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The SESAME I Experiment, Acoustic Data Processing and Catalog

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13. ABSTRACT *(Maximum 200 words)*

The first Shelf Edge Study Acoustic Measurement Experiment, SESAME I, was conducted August/September, 1995. The experiment took place at the Malin Shelf (56°33′ N, 9°0′ W) with the objective of determining the effects of solitary internal waves on acoustic fluctuations at the shelf edge. This paper describes the preliminary analysis of the narrow band continuous wave (CW) acoustic data from the three acoustic legs of the experiment. The acoustic data sets were collected using two Data Acquisition Buoy Systems (DABS), the first deployed in shallow water (170 m) at the shelf edge and the second deployed approximately 6100 m down slope in 500 m of water. Acoustic measurements were made over a frequency band of 100 to 2100 Hz with CW tonals broadcast at 150, 400, 800, and 1600 Hz. The signals were transmitted at source depths of 20, 50, and 100 m at multiple ranges from the array. System calibration analysis revealed both systems had low system noise floors and a flat amplitude response from approximately 125 Hz to 2000 Hz for all channels. The shallow-water DABS system had two hydrophones with an amplitude offset; calibration values applied to the data correct for these offsets. System calibrations have been applied to the acoustic results to produce transmission loss values versus source receiver range. Received levels were highest from the 500 m source depth at all frequencies and at both array locations. Both the 20 m and 100 m source depths often had very low signal to noise ratios, limiting the amount of reliable TL data. The deep-water DABS system had a lower dynamic range that resulted in the loss of acoustic data on the top three phones of the array. This was due to high noise levels during all events, probably associated with flow noise past the phones (the mean current speed was 10 to 40 cm/s) and wind-wave generated noise. Fishing vessel activity was noticeable in the data during several of the acoustic events, in particular during leg 3 when weather conditions were calmer. This activity often masked the acoustic signals up to 800 Hz.

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INTRODUCTION

The first Shelf Edge Study Acoustic Measurement Experiment, SESAME I, was conducted in August/September, 1995. The experiment took place at the Malin Shelf (56°33'N, 9°0'W) with the objective of determining the effects of solitary internal waves on acoustic fluctuations at the shelf edge. The experiment included investigators from the Naval Research Laboratory, Stennis Space Center (NRL/SSC), the Defense Evaluation Research Agency (DERA), United Kingdom, and the Natural Environment Research Council (NERC), United Kingdom.

During SESAME I, oceanographic measurements were made by the NERC ship, Challenger (cruise SES3), the NERC moored oceanographic arrays, and SAR images of the experimental area. Acoustic and oceanographic measurements were made by the DERA sonobuoys and AXBT's, and the DERA research vessel, Colonel Templer. NRL deployed two vertical arrays from the Colonel Templer. Figure 1 is a schematic depiction, drawn to scale, of all the experimental measurements. The location of the two acoustic arrays are depicted as squares while the source tracks are shown as solid heavy lines. Solid circles give the locations of the NERC oceanographic arrays (thermistor chains interspersed with current meters). Oceanographic surveys are shown by crooked lines.

The acoustic data sets were collected using two Data Acquisition Buoy Systems (DABS), the first deployed in shallow water (170 m) at the shelf edge and the second deployed approximately 6100 m down slope in 500 m of water. Acoustic measurements were made over a frequency band of 100 to 2100 Hz with CW tonals broadcast at 150, 400, 800, and 1600 Hz. The signals were transmitted at source depths of 20, 50, and 100 m at multiple ranges from the array.

This report documents experiment geometries and equipment used during the exercise, events as they transpired, and objectives that were accomplished. The experiment description information has been repeated from Field and Scott[1] and is included for completeness. The present report assesses the quality of the narrow band continuous wave (CW) data collected, provides plots and tabulations of these data, and describes the preliminary analysis of the acoustic data from the experiment. All dates and times are reported in Zulu (Z). Local time equals Z plus 1 hour.

EXPERIMENTAL GEOMETRY

Sensor Description

Acoustic data were recorded using two DABS systems, the NRL Data Acquisition Buoy System (NDABS) deployed in 170 m of water at the shelf edge and the AEAS Data Acquisition Buoy System (ADABS) deployed 6100 m down slope of the shallow array in 500 meters of water (Figure 1). Figures 2a and 2b show the two array configurations. The top hydrophone for each system was at a depth of 20 m. Each array is anchored to the ocean bottom with a 3000 lb weight attached to an acoustic release.

Both NDABS and ADABS consist of 31 hydrophone elements, a preamp to monitor system noise, and an Instrumented Pressure Vessel (IPV) that houses the tape recorder and associated electronics. For the shallow array, the 31 elements were evenly spaced at 4.5 m. For the deep array, the first 21 hydrophones are spaced at 4.5 m as in the shallow array case. The remaining ten hydrophones of the deep array were spaced 37.5 m apart to span the rest of the water column.

The tape recorders of each DABS system can be programmed to turn on and off at designated times. Up to 50 hours of acoustic data can be recorded on each system. The legs of the experiment correspond to these 50 hour segments. After 50 hours of acoustic data was recorded, both systems were retrieved, refurbished and then redeployed for another experimental leg.

Each system was fitted with current and temperature meters at the top and bottom of the array. These sensors were approximately 10 meters below the ocean surface and 15 meters above the ocean bottom.

Sources and Signals

The Colonel Templer was equipped with five Gearing and Watson acoustic sources which transmitted their respective signals simultaneously. Three of the sources were deployed as a unit off the starboard side and transmitted 400, 800 , and 1600 Hz CW signals. These signals had source levels of 161.3, 160.3 and 161.7 dB re 1 m respectively. During leg 1, these sources were initially deployed at 100 meters and some CW measurements at 400, 800, and 1600 Hz were made at this depth. During

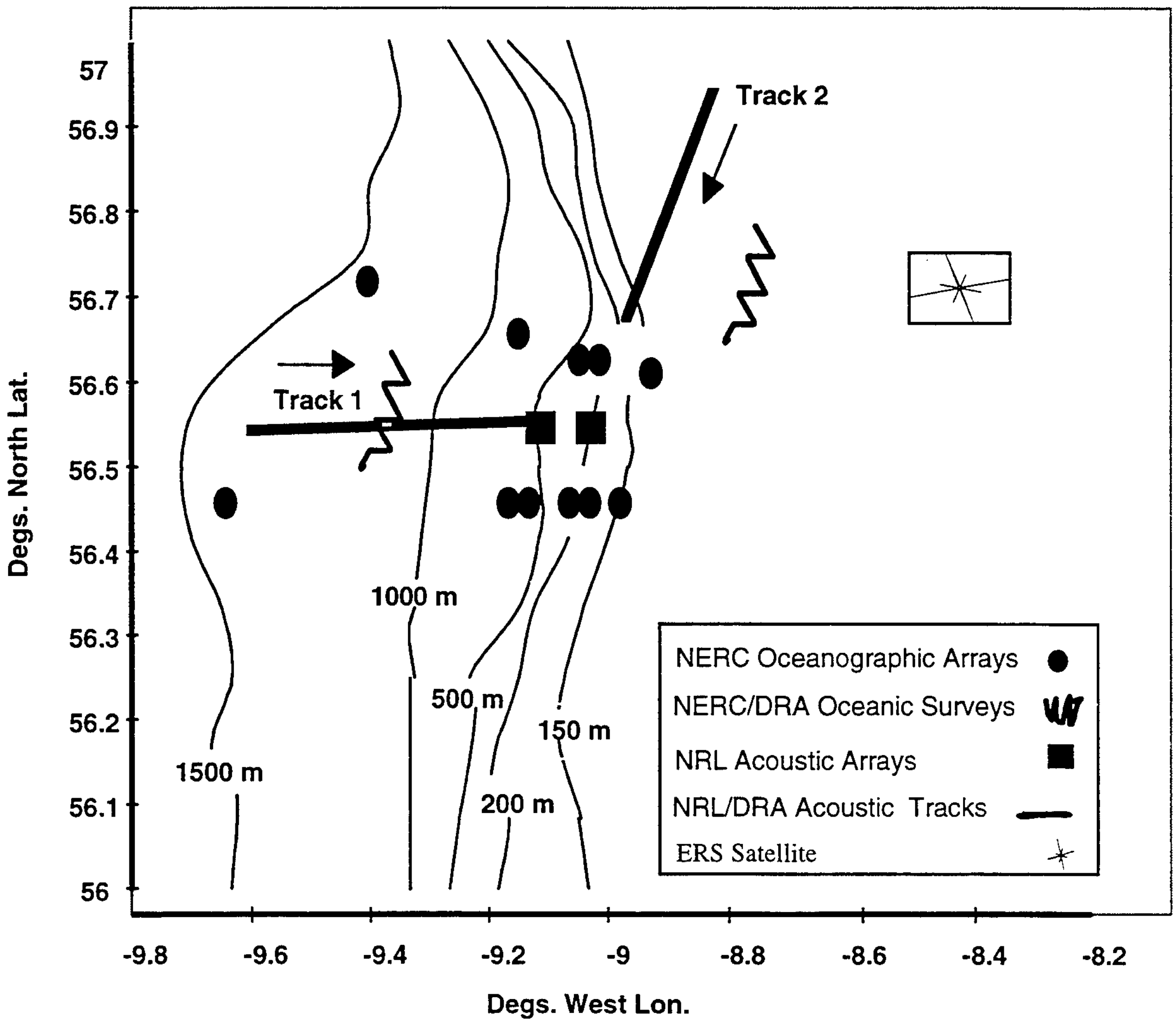


Figure 1. Plan view of SESAME I.

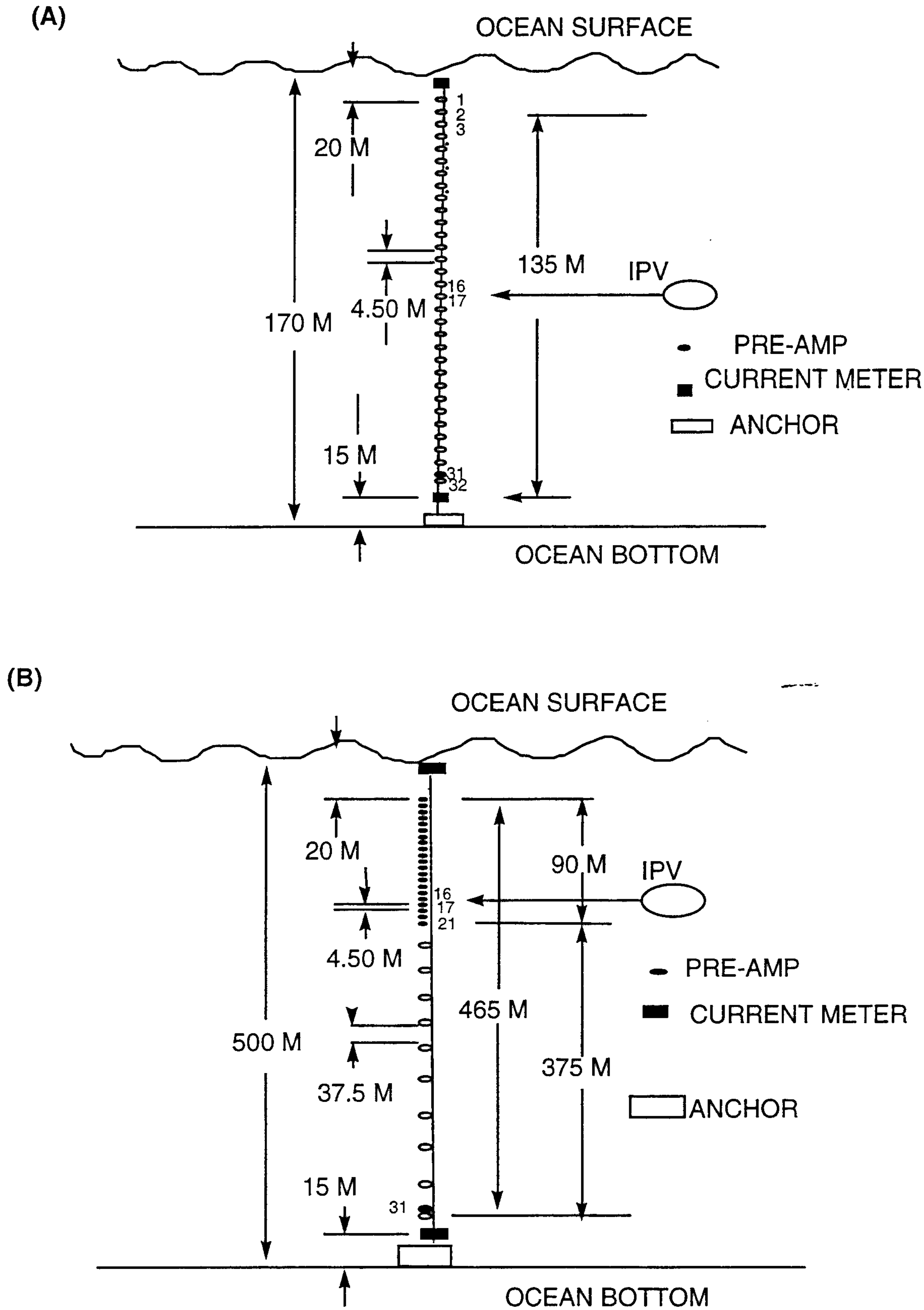


Figure 2. Array configuration for (a) the shallow water (NDABS) site and (b) the deep water (ADABS) site.

the remainder of leg 1, these sources were deployed at 20 or 50 meters instread of 100 meters in order to prevent tangling with the other two sources deployed off the stern. The sources deployed off the stern transmitted 150 Hz CW (source level of 163.9 dB re 1 m) and FM signals. These sources were operated at depths of 100, 50, and 20 meters. At some of the shallower stations along the slope, all sources were deployed at only 50 and 20 meters. Since the mixed layer was found to be changing between 20 and 100 meters during the experiment, legs 2 and 3 had all sources deployed at 50 m.

Figure 3a gives a frequency domain description of the FM and CW signals that were transmitted. FM signals 1 through 5 were swept over the specified frequency bands. Figure 3b shows a time domain picture of the 5 FM signals shown in figure 3a. Each FM signal was swept up in frequency for 30 seconds then back down for another 30 seconds over the bandwidths given in Figure 3a. The bandwidths are stepped through sequentially, therefore there are four minutes of off time before a frequency band is re-broadcast. The FM signals were repeated over a 30 to 40 minute period at each source depth. As the FM signals were being transmitted, the four CW signals, denoted by the vertical arrows in Figure 3a, were transmitted continuously over the 30 to 40 minute time period.

Acoustic Measurements

Acoustic events were conducted with the Colonel Templer in a quiet mode of operation. This means that the ships engines were off and the ship simply drifted with the current. During many events this resulted in a large change in ship position, even during "constant range" or "time varying" events. Even in the quiet mode of operation, the ship put out broadband noise at frequencies < 800 Hz which could be detected at close range. This noise was primarily from the stern aspect and did not appear to effect the propagation data.

Each system was deployed three times during SESAME I; these recording periods are referred to as legs 1, 2, and 3. Each leg was designed with different experimental objectives in mind. These are discussed in the following sections.

(A)

(B)

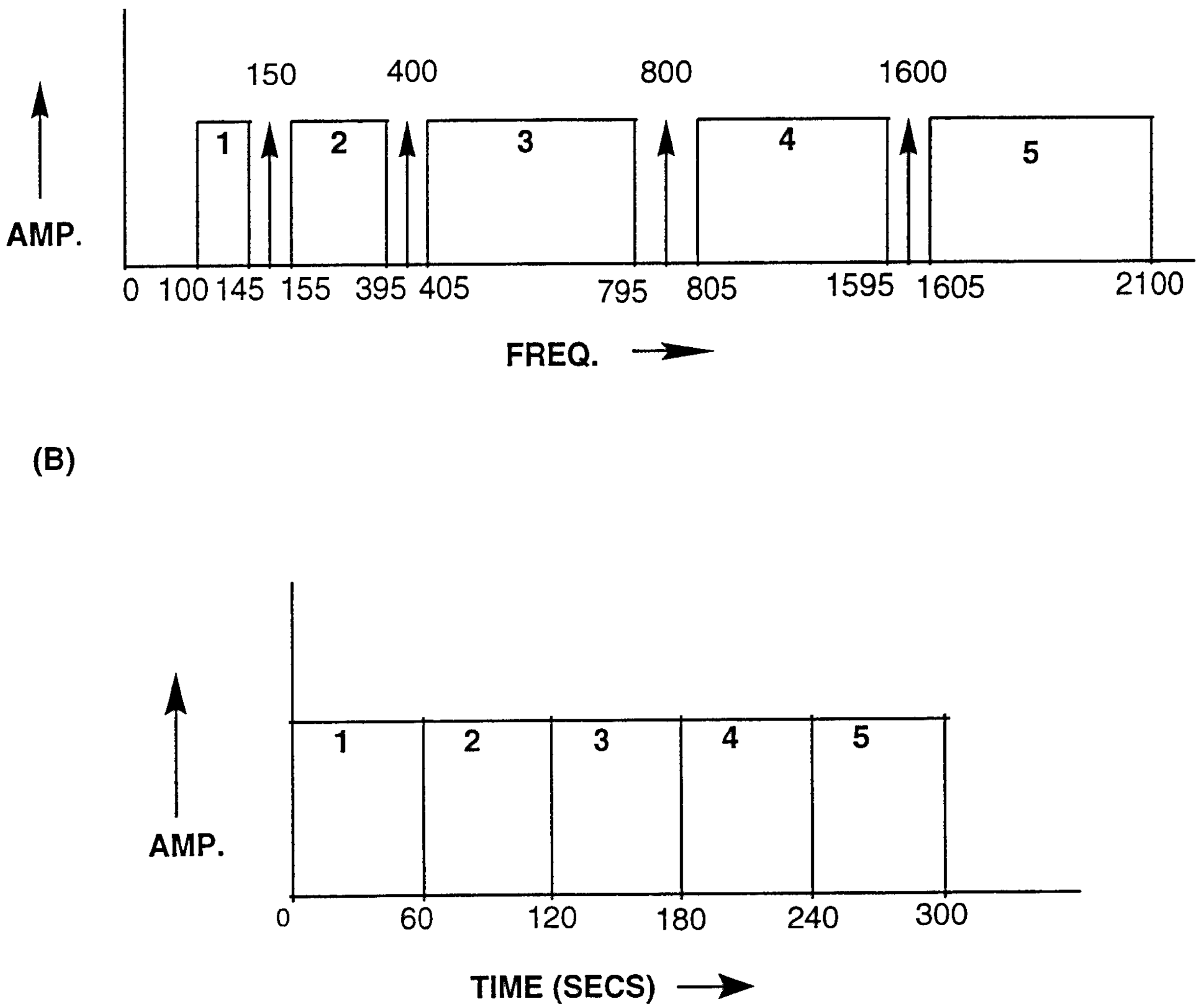


Figure 3. (a) *Frequency* description of transmitted signals and (b) *Time* description of FM signals.

Leg 1: Range Varying Transmission

Leg 1 was designed to collect propagation data at varying ranges and source depths in both upslope and along slope directions. Upslope refers to events where the acoustic arrays were upslope of the source, or said another way, the transmission of the signals was in the upslope direction. Along slope events were designed to have nearly constant bottom depth between source and receivers. Figure 4 shows the position of the Colonel Templer at the 40U, 30U, 25U, 20U, 15U, and 10U "stations". The U denotes upslope propagation to the two arrays. The position of the ship is shown every 15 minutes. The beginning and ending times are also given for each station. The labels 40U, 30U, etc., indicate the beginning of the "station". DA and SA show the positions of the deep and shallow arrays, respectively. The position of DA was 56.55°N, 9.12°W in a water depth of 174 m. SA was positioned at 56.5505°, 9.0064°W in a water depth of 506 m. The vertical and horizontal axes are given in tenths of a degree. Every minute of longitude is approximately 1021 meters or 0.55 NM and every minute of latitude is approximately 1852 m or 1 NM.

The along slope stations, labeled A, are shown in figure 5. Stations 20A and 40A were longer than the others because minimum detectable level measurements were made in addition to transmission loss. The squares labeled with the time and date indicate the positions of XBTs taken along the track. Source depths were changed at each station during the leg. Table 1 lists the start times and duration at each source depth for each station.

Leg 2: Continuous Transmission

The purpose of leg 2 was to obtain broadband propagation data at a constant range over two semi-diurnal tidal periods for both up slope and along slope acoustic propagation. The source depth was 50 meters for the entire leg. Figure 6 shows the ship positions for the up slope portion of leg 2. During this portion of the leg the deep array could not be deployed because of bad weather. The shallow array was deployed at 56.5503°N, 9.02°W just before the onset of rough seas. The water depth at the array location was 174 m. Winds gusting to 50 knots and wave heights from 6 to 7 meters were experienced during most of the up slope transmission. Wave height and

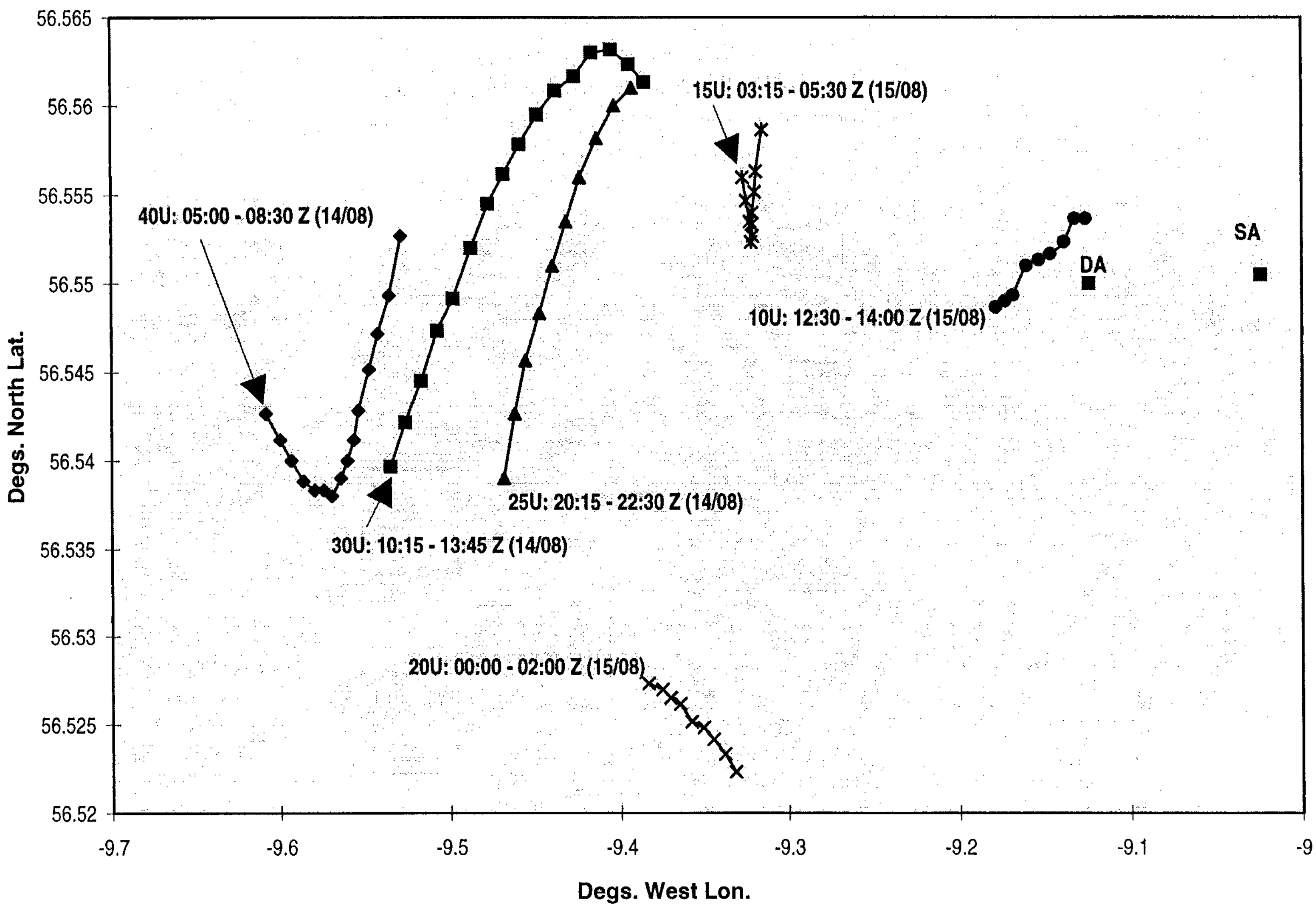


Figure 4. Stations 40U, 30U, 25U, 20U,15U and 10U of Leg 1.

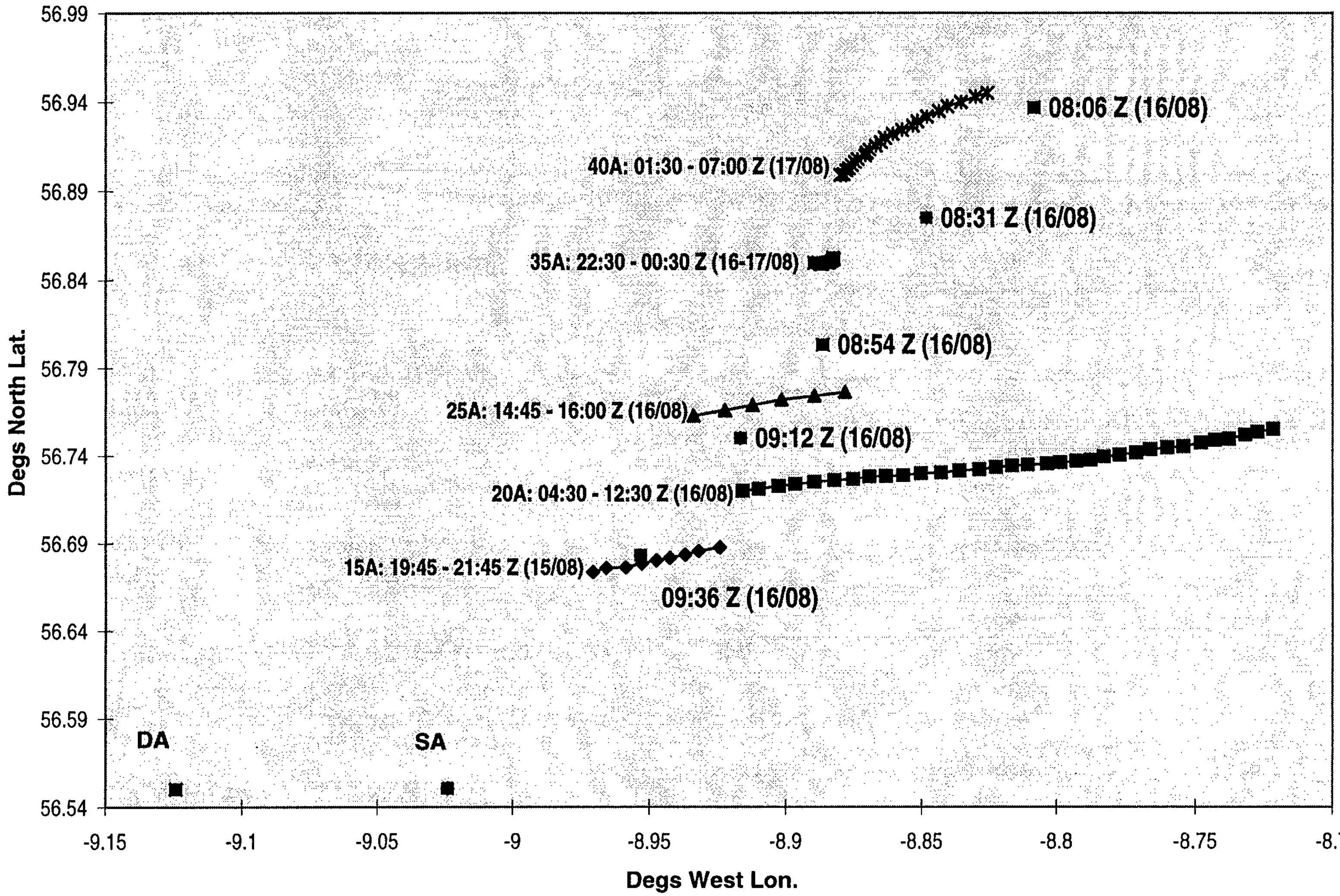


Figure 5. Stations 15A, 20A, 25A, 35A, and 40A of Leg 1.

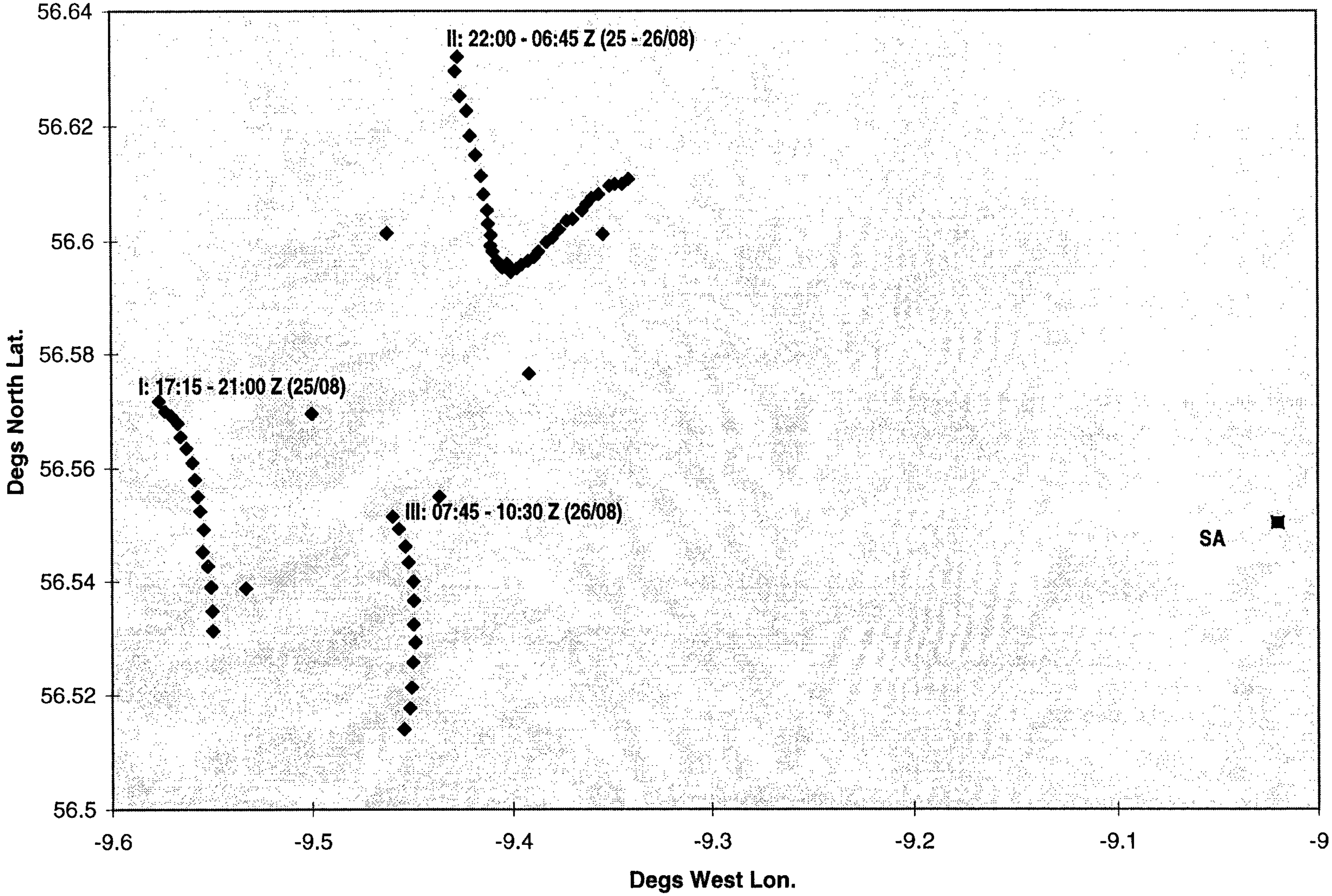


Figure 6. Stations 25U-I, 25U-II, and 25U-III of Leg 2.

Table 1. SESAME I source depths, event start times (Zulu), and event duration times (mins). Sources started deep and were brought up over the course of the event. Each column contains the start date/start time/event duration.

LEG	EVENT	150 Hz SOURCE DEPTH			400, 800, & 1600 Hz SOURCE DEPTH		
		100 m	50 m	20 m	100 m	50 m	20 m
1	40U	226/0535/43*	226/0717/73	226/0618/59	226/0455/142	226/0717/73	
1	30U	226/1025/103	226/1211/52	226/1315/45		226/1020/160	226/1315/45
1	25U	226/2018/42	226/2100/50	226/2150/41		226/201892	226/2152/41
1	20U	226/2340/47	227/0027/53	227/0120/40		226/2340/100	227/0120/40
1	15U	227/0325/41	227/0406/46	227/0452/53		227/0325/87	227/0452/53
1	10U	227/1237/40	227/1317/29			227/1237/69	
1	15A	227/1951/33	227/2024/30	227/2103/27		227/1951/63	227/2103/27
1	20A	228/0430/28	228/0505/31	228/1148/28		228/0430/59	228/1148/108
1	25A		228/1454/31	228/1534/26		228/1454/31	228/1534/26
1	35A		228/2241/50	228/2332/53		228/2241/50	228/2337/56
1	40A		229/0130/40	229/0723/37		229/0130/40	229/0625/35

* 86 m source depth

ship roll are shown as a functions of time in Figures 7a and 7b respectively. The maximum wave heights and ship roll were recorded on August 25, the day of the up slope portion of leg 2. Acoustic transmission scheduled to begin at 11:00 Z on August 25, was delayed until 17:30 Z. Figure 6 shows that the ship repositioned twice during this portion of leg 2. Roman numerals I, II, and III in the figure refer to the positions of the ship for "station" 25U. Beginning with this leg a CTD sensor was strapped to the 3 starboard sources so that a continuous temperature and depth record at the source depth could be obtained.

Before the along slope portion of leg 2, the weather improved enough to allow deployment of the deep array and the thermistor chain. The deep array was deployed at 56.549°N, 9.1235°W in a water depth of 502 m. Shortly after the acoustic sources were deployed for along slope transmission, the weather turned foul again, preventing the recovery of the sources. Even though figure 7a shows that the peak wave heights decreased from August 25 to August 27, figure 7b shows that the roll of the ship was

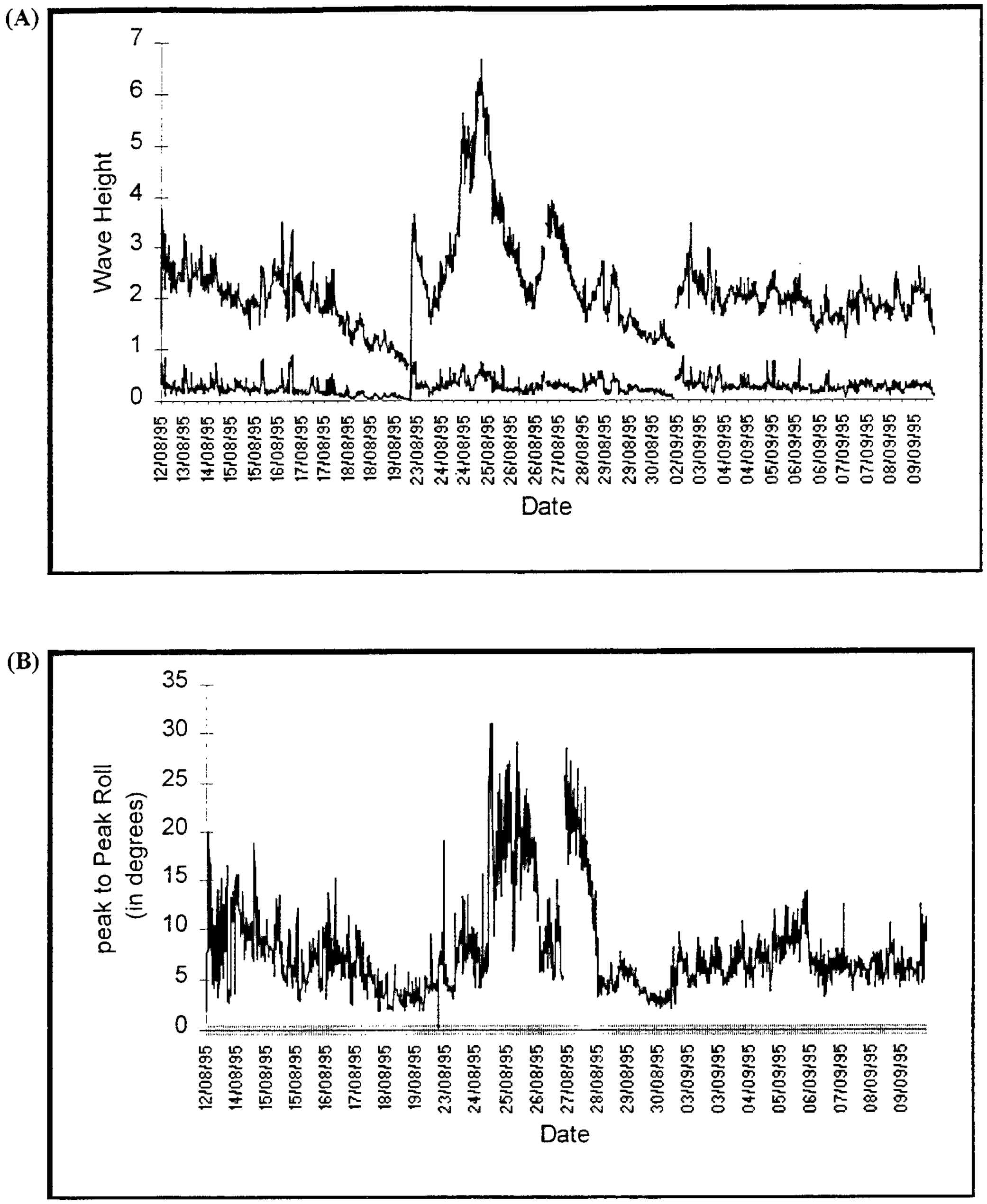


Figure 7. Summary of SESAME I (a) significant wave height and (b) peak-to-peak ship roll within a fifteen minute period.

about the same during these time periods. It was excessive ship roll that prevented the recovery of the sources. Figure 8 shows the ship positions for what was supposed to be the constant range station at 25A. Since the starboard deployed sources could not be towed, the ship could not be repositioned as was done for the 25U station of leg 2. By the time the weather improved enough for the sources to be recovered, the ship was far past the 25A position. Too much DABS recording time would have been lost while trying to reposition the ship and redeploy the sources. Therefore it was decided to drift and transmit for the remaining DABS recording time. This track should prove to be a reasonable range varying track in the along slope direction.

Leg 3: Continous Transmission and Minimum Detectable Level

Because of the bad weather encountered during leg 2, some of the continuous transmissions in the along slope directions were attempted again during leg 3 which was originally devoted to minimum detectable level measurements. The first three DABS recording time periods (10 hours, 10 hours, and 3 hours) were devoted to continuous transmission in the along slope direction with a source depth of 50 m. These tracks are referred to as 25A-I, 25A-II, and 25A-III, respectively (Figure 9). As before, the Roman numerals mark the beginning of the tracks. The positions of the deep and shallow arrays are 56.5467°N, 9.1235°W and 56.55°N, 9.0275°W, respectively. The water depths at the two array locations were 508 and 183 m.

RECORDING EQUIPMENT

Equipment Description and Tape Transcription

The DABS units are self-recording battery operated programmable buoy systems designed to collect data remotely. Each system consists of a signal conditioning unit, analog-to-digital (A/D) convertor and a single 15 inch reel DDR100 tape recorder. These recorders are capable of storing 250 gigabytes of data. System gains must be set prior to sealing the IPV and are typically set prior to system calibration for an exercise. System gains of 44.3 dB and 62.0 dB were used for the NDABS and ADABS respectively.

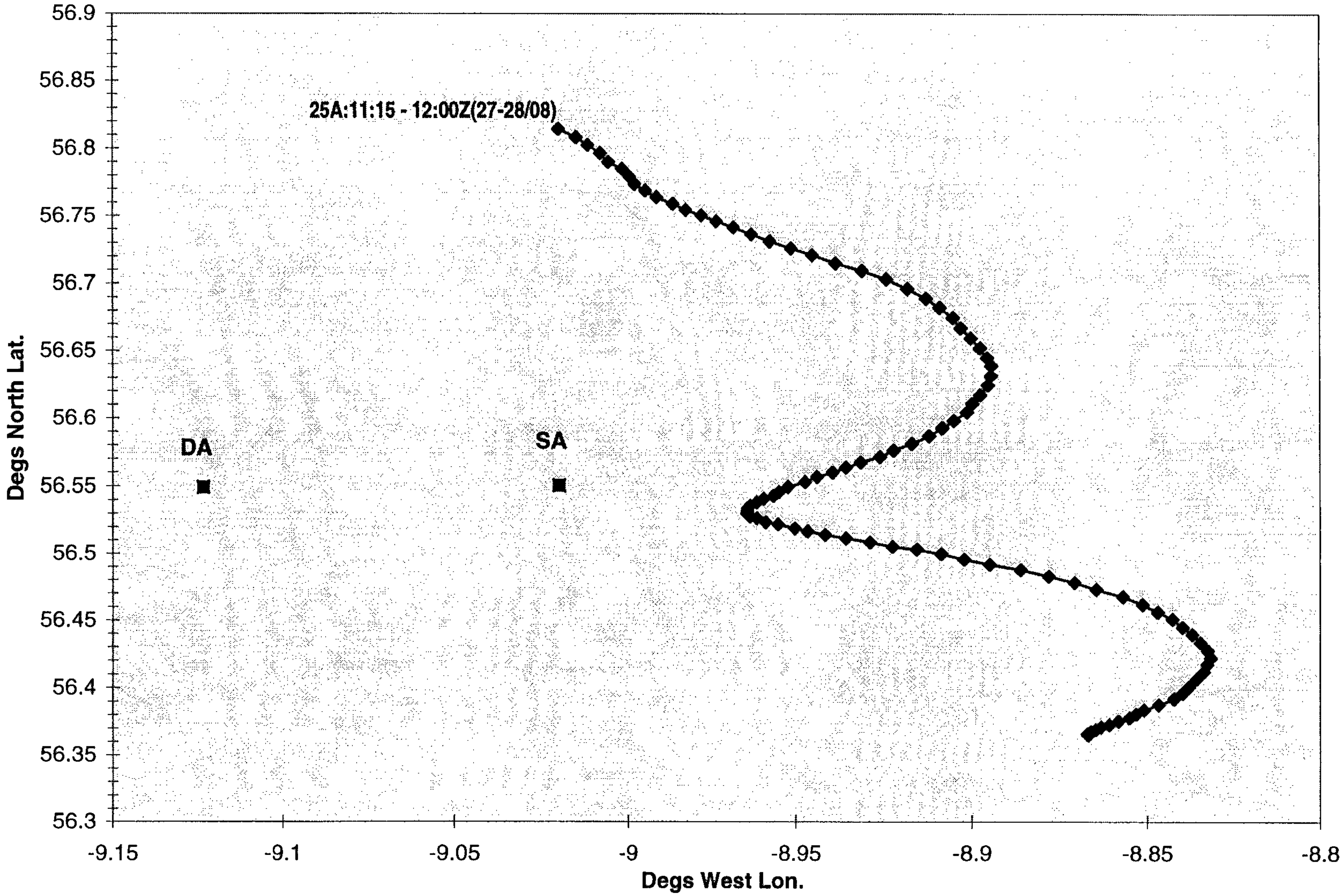


Figure 8. Station 25A of Leg 2.

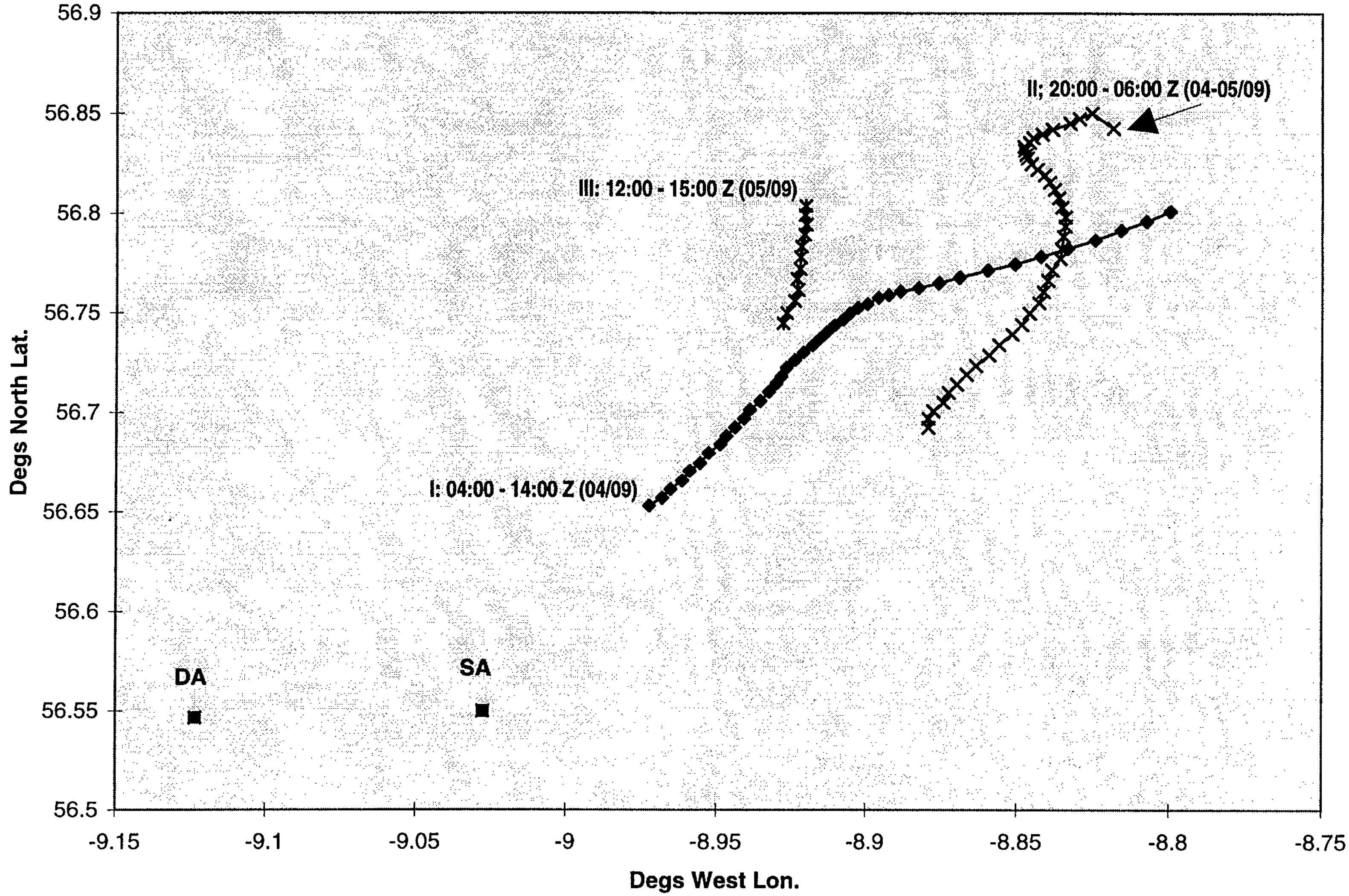
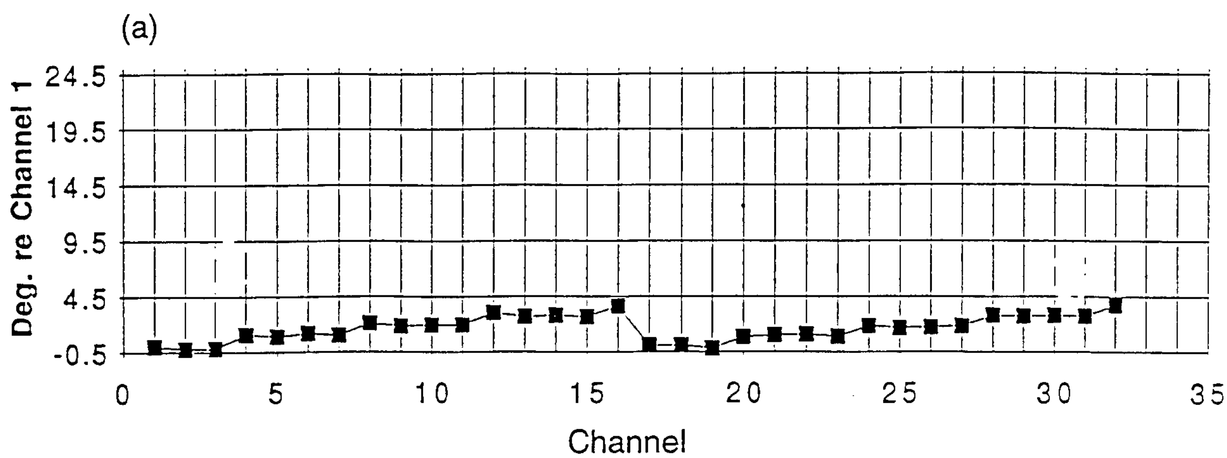


Figure 9. Continuous transmission of Leg 3.

Each system can record up to 50 hours of acoustic data. The tape recorders can be programmed to turn on and off at user prescribed times. Since the DABS units are designed to operate remotely, the units record equipment performance information in each record header on the tape followed by the output voltage from each hydrophone. The equipment performance information includes the data records' start time, battery voltage, and overload status words. Battery voltages have been examined by the system engineer. Low battery voltages result in system shutdown but do not degrade the data quality prior to shutdown. There are two 16-bit overload status words in the header, each bit is set individually for each recording channel when an overload is detected on that channel. In addition to the equipment performance words, the DABS units are typically deployed with one preamplifier which does not have an associated hydrophone; this is used to record system noise levels. These system records have been critical in determining system related noise during past deployments. During SESAME I, the preamp was recorded on channel 31 of both systems except for leg 3 . Channel 31 was required for another hydrophone therefore there is no system phone on the shallow NDABS during leg 3.

While the two units are designed to function the same way, there are subtle differences in how these systems operate which effects data processing. The A/D converter in ADABS uses a 16 bit 2.5 V reference successive approximation A/D (classical A/D) which means that recorded voltages from the hydrophones can be inspected to determine if the system was overdriven during recording (the dynamic range of the ADABS system is conservatively 80 dB). Secondly, the ADABS system samples in eight channel groups with a theoretical static time delay between sample groups. During a previous deployment the static phase shift was determined from header calibrations (Figure 10) and was found to agree with the theoretical shift and was also found to be stable over time. Therefore simple time delay corrections could be applied to the data prior to phase coherent processes such as beamforming. Finally, the first overload status word in each record header of ADABS represent channels 17 thru 32 while the second word represents channels 1 thru 16.

The larger dynamic range of the NDABS system (conservatively 100 dB) often results in significantly less clipping, particularly when a sound source is close by or very



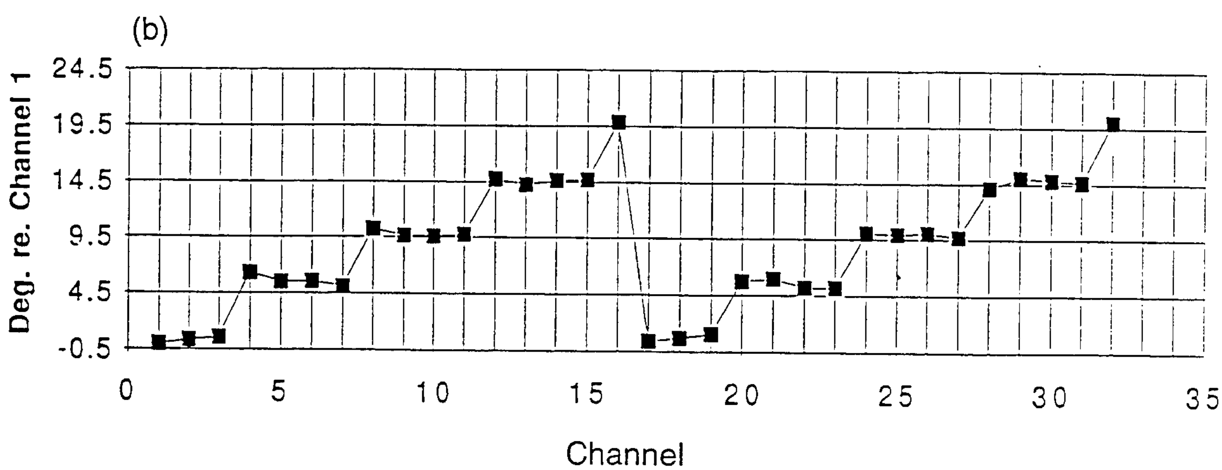


Figure 10. Examples of the static phase shift in the ADABS system for (a) 190 Hz and (b) 950 Hz. These examples are from a header calibration during a previous deployment.

variable in level. NDABS uses a 16 bit sigma delta A/D. This A/D has a digital signal processing (DSP) circuit on the chip which oversamples the signal and then filters it prior to the systems anti-alias filter. Overload words are set for any channel(s) which experiences clipping, however the analyst cannot tell by inspection if the data has been clipped and must rely on the overload words. System engineers recommend that whenever this word is set, the entire record should be discarded. NDABS simultaneously samples all channels which results in nearly identical phase for all channels. Therefore, coherent processing can be performed on the data directly. Finally, for NDABS, the first overload status word in each record header represents channels 1 thru 16 while the second word represents channels 17 thru 32.

Digital data from the DABS units has to be transcribed from the recording tape to exabyte tape before processing. This transcription process places the data into ADIOS format. The data is stored as 16-bit, two's complement, integer words. There is no byte reversal. A/D parameters are constant throughout the data set, that is, sample rate, hydrophone order, and so on, do not change. The data set is subdivided into subsets as shown in Figure 11 with the record being the lowest subdivision. The diagram does not necessarily represent the actual number of subdivisions, but rather is intended as an example of the hierarchy of subsets. A tape header is written out first and contains information pertinent to the exercise, transcription process, array deployment, and hydrophone channel assignments and sensitivites (Figure 12). During transcription, time discontinuity or breaks in time between successive records, are detected and flagged in the output record header. These time discontinuities result from system startup and shutdown and may occur occasionally during recording.

A record of DABS data contains a 32 word header (Figure 13) followed by 16384 words of acoustic data (16416 total words/record). This equates to 512 samples/hydrophone in each record (16384/32=512). Each hydrophone is recorded sequentially; the data pattern is shown in Figure 11. Each record comprises 0.09437 secs of data (#samples/sample rate or 512/5425.3472), each sequence contains 636 records and each file generally contains 52 sequences. This means each file is 52 x 636 x 0.09437/60 or 52 minutes long.

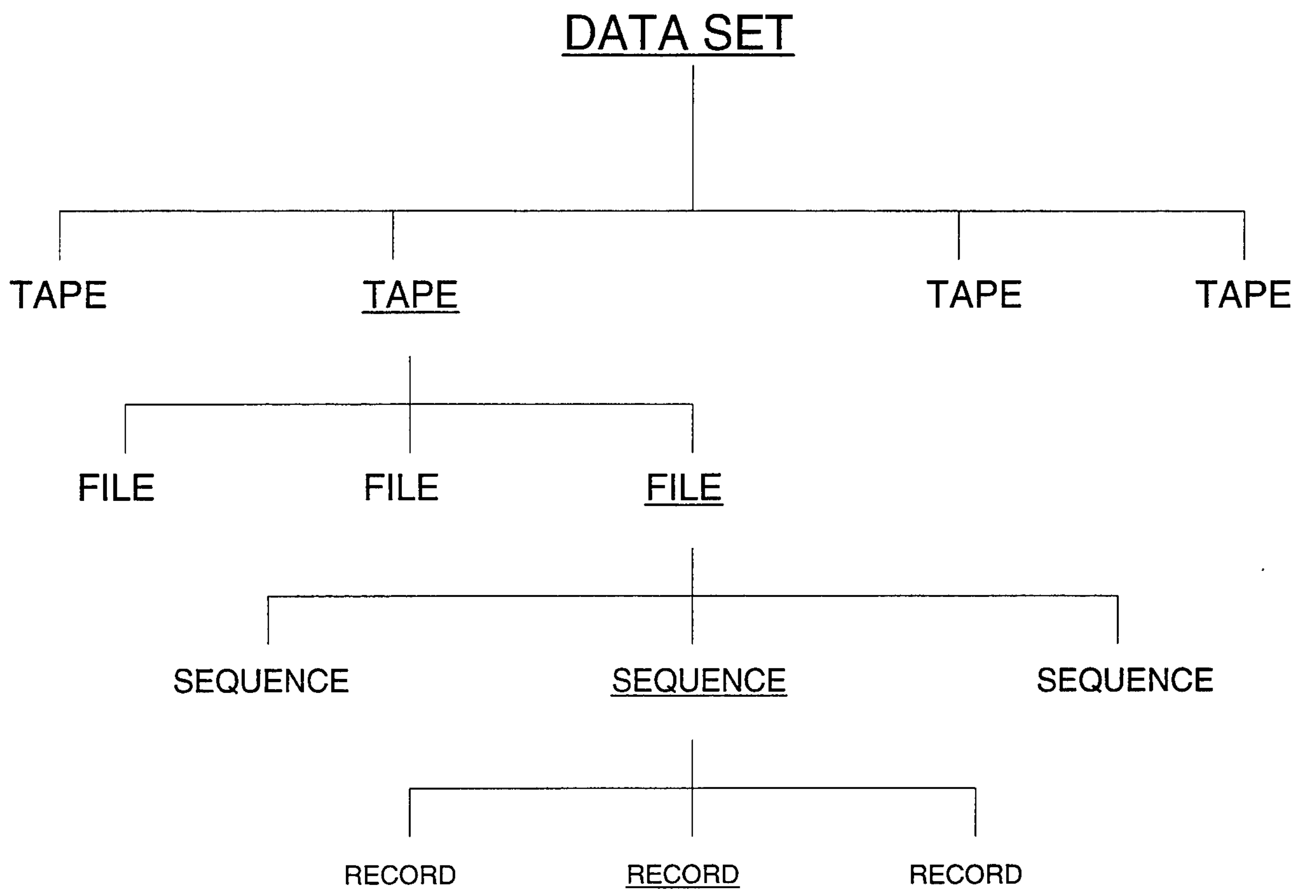


Figure 11. ADIOS format subset hierarchy.

Type	Name	Bytes	Usage
char	type;	1	type of record; G=GUFI or D=data
char	machine;	1	type of computer used
unsgn sht	hlength;	2	header length
unsgn sht	rlength;	2	record length
unsgn sht	files;	2	file number
unsgn sht	recs;	2	record number in this file
unsgn sht	seqs;	2	sequence number in this file
unsgn sht	recseq;	2	record number in this sequence
unsgn sht	recsinseq;	2	records in the sequence; use 0
unsgn sht	status;	2	status flags; use 0
unsgn sht	hour;	2	hour of the year; starts at 24
unsgn sht	sec;	2	second of the hour
unsgn sht	msec;	2	millisecond of the second
unsgn sht	channels;	2	number of channels
unsgn sht	format;	2	data format
unsgn sht	tbd1;	2	dummy
unsgn sht	tbd2;	2	dummy
unsgn sht	dabsformat;	2	identifies data and header format
char	name[82];	82	excercise name
char	system[82];	82	system name
char	note1[82];	82	general notes
char	note2[82];	82	general notes
char	note3[82];	82	general notes
char	note4[82];	82	general notes
char	time[18];	18	data start date-time(yymmdd-hhmm)
unsgn sht	tape;	2	tape number
unsgn sht	numch;	2	number of channels
float	vref;	4	reference voltage
double	fs;	8	sample frequency
--------------Begin Group for each hydrophone, 32 in all-------------			
unsgn sht	ch;	2	channel number
unsgn sht	hyd;	2	hydrophone number
long	sn;	4	hydrophone serial number
float	loc;	4	hyd loc., meters relative to H1
float	sen;	4	hyd midband sensitivity
float	res;	4	termination resistance for s
float	gain;	4	midband gain
double	cnts;	8	counts per uPa
----------------------End Group for each hydrophone------------------			

Padding at end of record out to 32832 bytes
Total bytes for TAPE HEADER 32832

Figure 12. ADIOS tape header format.

Type	Name	Bytes	Sum	Usage
char	type;	1	1	type record; G=GUFI or D=data
char	machine;	1	2	type computer used
unsgn sht	hlength;	2	4	header length
unsgn sht	rlength;	2	6	record length
unsgn sht	files;	2	8	file number
unsgn sht	recs;	2	10	record number in this file
unsgn sht	seqs;	2	12	sequence number in this file
unsgn sht	recseq;	2	14	record number in this sequence
unsgn sht	recsinseq;	2	16	records in the sequence; use 0
unsgn sht	status;	2	18	status flags; use 0
unsgn sht	hour;	2	20	hour of the year; starts at 24
unsgn sht	sec;	2	22	second of the hour
unsgn sht	msec;	2	24	millisecond of the second
unsgn sht	channels;	2	26	number of channels
unsgn sht	format;	2	28	data format
unsgn sht	tbd1;	2	30	unused
unsgn sht	tbd2;	2	32	unused
unsgn sht	discont;	2	34	0==>OK, 1==> Data Gap occurred
unsgn sht	eng1;	2	36	engineering ch1
unsgn sht	eng2;	2	38	engineering ch2
unsgn sht	eng3;	2	40	engineering ch3
unsgn sht	eng4;	2	42	engineering ch4
unsgn sht	eng5;	2	44	engineering ch5
unsgn sht	eng6;	2	46	engineering ch6
unsgn sht	eng7;	2	48	engineering ch7
unsgn sht	eng8;	2	50	engineering ch8
unsgn sht	stat1;	2	52	status word 1
unsgn sht	stat2;	2	54	status word 2
unsgn sht	ovld1;	2	56	overload word 1
unsgn sht	ovld2;	2	58	overload word 2
unsgn sht	tbd3;	2	60	unused
unsgn sht	tbd4;	2	62	unused
unsgn sht	tbd5;	2	64	unused

Acoustic Data Layout -- 32768 Bytes

Figure 13. ADIOS record header format contained in bytes 1-64, followed by acoustic data in bytes 65-32832. Note the first 15 fields are the same as in the tape header.

Calibrations

Recorder system calibrations were performed in the field prior to each deployment for each system. Analysis of this calibration data provides information on variability of both amplitude and phase from hydrophone to hydrophone. Experiment calibration amplitudes are checked against preexperiment amplitudes to ensure that no significant changes occurred in the equipment during the experiment. Calibrations were performed by sending a reference signal into the signal conditioning unit (SCU), to replace the analog signal coming from the array. In this way, calibrations of the recording and playback systems were produced that can be used in conjunction with the hydrophone sensitivities to calculate sound pressure level in dB re 1 μPa. Calibration signals were recorded at the beginning of each field tape in what is called the header calibration. Four sets of recordings typically comprise the header calibration: self noise (no input signal), broadband noise, sine wave signals input on all channels simultaneously, and sine wave signals input on individual channels sequentially (to identify each channel).

System calibration analysis revealed NDABS had a low system noise floor and a flat amplitude response from approximately 125 Hz to 2000 Hz for all channels (Figure 14a). NDABS had two channels, 2 and 10, with amplitude offsets of approximately 2.7 dB from the rest of the channels. Calibration values applied to the data corrected these offsets. The ADABS system calibration indicated a slightly higher noise floor with distinct recording system generated lines at frequencies of 340, 678, 758, 1017, 1144, 1284, and 1687 Hz (Figure 14b). These lines were 8-14 dB higher than the average noise floor. System generated lines were not observed during the high level broadband portion of the calibration (Figure 14a) or in the recorded hydrophone data, even during periods with low ambient noise levels. Channel to channel variability across the recording bandwidth was <0.5 dB (for both recording systems, disregarding the two NDABS outlier channels).

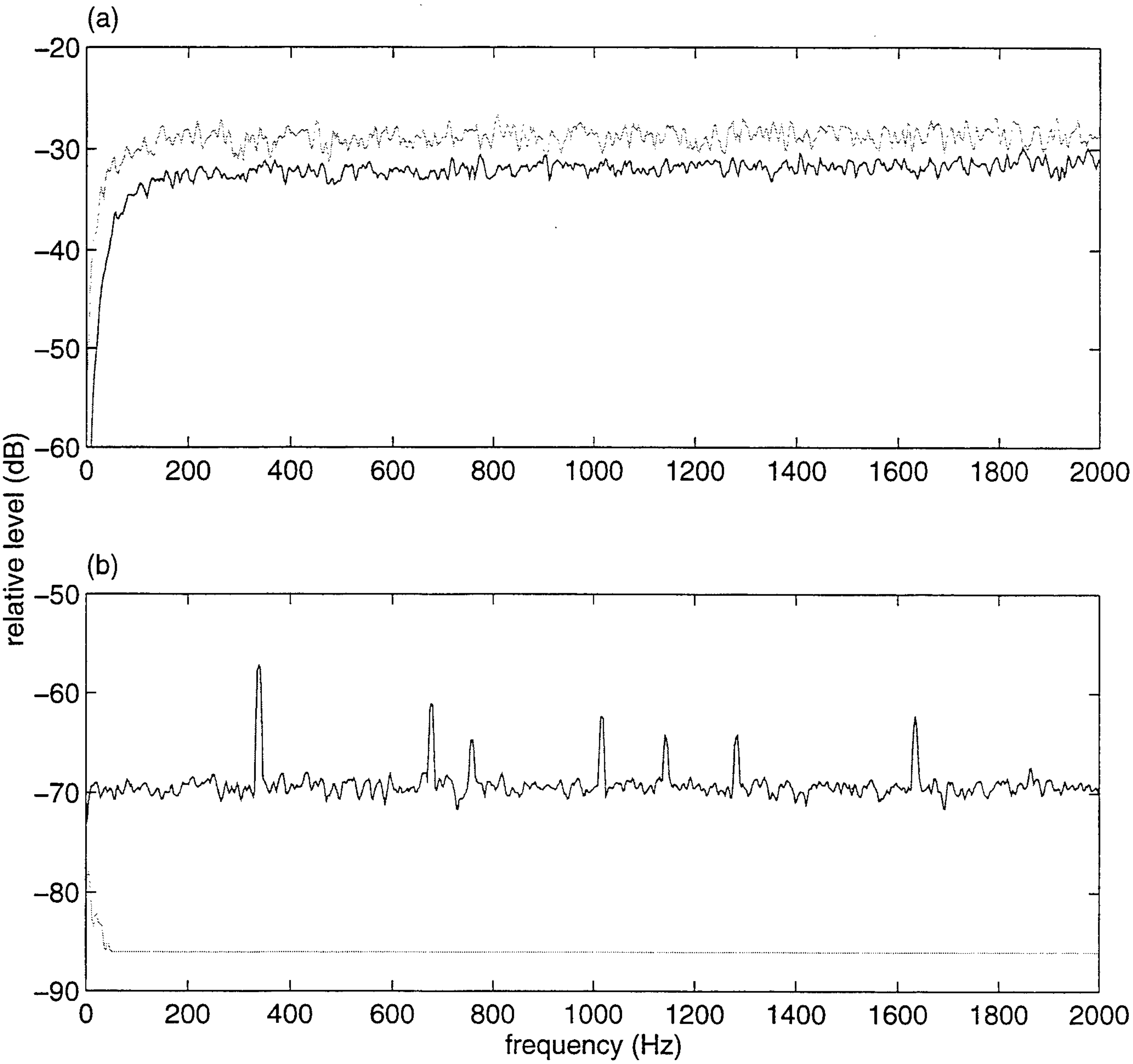


Figure 14. NDABS (gray) and ADABS (black) calibration data (a) showing the response of each system during the white noise tests, and (b) showing the system noise floors.

Hydrophone sensitivities

Hydrophone sensitivities were determined from calibrations done on 20 September 1993 at the Naval Research Laboratories' Underwater Sound Reference Detachment in Orlando, FL.[2-6] Midband sensitivities for all hydrophones used on both systems averaged -176.9 dB with a standard deviation of 0.32 dB. Midband sensitivities for each hydrophone on both systems are listed in Table 2. Recall that the NDABS array was reconfigured for leg 3 and is thus listed separately from legs 1 and 2.

Table 2. Hydrophone channel assignments, sensitivities and depths for ADABS and both NDABS configurations.

	ADABS DEEP WATER ARRAY				NDABS LEG 1 AND 2 SHALLOW WATER ARRAY				NDABS LEG 3	
CHANNEL	PHONE	SERIAL #	DEPTH (M)	SENSITIVITY	PHONE	SERIAL #	DEPTH (M)	SENSITIVITY	PHONE	DEPTH (M)
1	1	2510149	20.0	-176.3	1	2510004	20	-177	1	20
2	2	2510150	24.5	-176.8	2	2510015	24.5	-177.2	2	24.5
3	3	2510155	29	-176.9	3	2510028	29	-177.3	3	29
4	4	2510156	33.5	-176.9	4	2510053	33.5	-177.1	4	33.5
5	5	2510157	38	-176.8	5	2510054	38	-177.8	5	38
6	6	2510158	42.5	-176.7	6	2510055	42.5	-177.1	6	42.5
7	7	2510159	47	-176.7	7	2510061	47	-176.6	7	47
8	8	2510160	51.1	-176.8	8	2510064	51.1	-176.9	31	154
9	9	2510161	56	-176.8	9	2510075	56	-177.9	9	56
10	10	2510162	60.5	-176.9	10	2510082	60.5	-177	10	60.5
11	11	2510163	65	-177.0	11	2510087	65	-177	11	65
12	12	2510164	69.5	-177.1	12	2510088	69.5	-176.3	12	69.5
13	13	2510166	74	-177.3	13	2510091	74	-176.8	13	74
14	14	2510168	78.5	-177.2	14	2510092	78.5	-176.3	14	78.5
15	15	2510170	83	-177.2	15	2510093	83	-176.5	15	83
16	16	2510172	87.5	-177.1	16	2510105	87.5	-176.4	32	155
17	17	2510173	92	-176.9	17	2510113	92	-176.4	17	92
18	18	2510178	96.5	-177.0	18	2510116	96.5	-176.6	18	96.5
19	19	2510179	101	-176.9	19	2510119	101	-176.4	19	101
20	20	2510181	105.5	-176.7	20	2510121	105.5	-176.4	20	105.5
21	21	2510183	110	-176.9	21	2510124	110	-176.5	21	110
22	22	2510184	147.5	-176.9	22	2510128	114.5	-176.7	22	114.5
23	23	2510185	185	-176.8	23	2510130	119	-176.9	23	119
24	24	2510186	222.5	-176.9	24	2510135	123.5	-177	24	123.5
25	25	2510188	260	-177.2	25	2510134	128	-176.8	25	128
26	26	2510189	297.5	-176.6	26	2510136	132.5	-176.8	26	132.5
27	27	2510190	335	-177.1	27	2510140	137	-177	27	137
28	28	2510191	372.5	-176.4	28	2510144	141.5	-177.3	28	141.5
29	29	2510194	410	-176.9	29	2510146	146	-176.8	29	146
30	30	2510195	447.5	-177.0	30	2510147	150.5	-176.9	30	150.5
31	31	0	484	0.0	31	0	154	0	8	51.1
32	32	2510196	485	-177.0	32	2510197	155	-176.4	16	87.5

ACOUSTIC RESULTS

Data Processing

Recorded data were processed using specialized Fortran software and an over the counter signal processing software package from MATLAB. The Fortran software is used to read in the ADIOS formatted data, perform spectral analysis and write MATLAB compatible binary files. Applications of system gains and further data editing were performed using MATLAB scripts.

Hann windowed FFT's (4096 pt FFT) were performed over a 2000 Hz bandwidth resulting in a binwidth of 1.325 Hz. Eighty (RMS) spectral estimates representing approximately 1 minute of data produced one time averaged spectra (mean square pressure) according to equation 1:

$$SPL = 20 \log \langle \sqrt{P_{Real}{}^2 + P_{Imag}{}^2} \rangle_{1\ min} \qquad (1)$$

where P is the power sound spectrum level in dB re 1 μPa. All spectral levels have been corrected for windowing effects. Corrections for processing bandwidth were applied to ambient noise data during data reduction so that reported sound power density spectrum levels are in dB re 1 $\mu Pa^2/Hz$ (see equation 2). Tables 3 and 4 show the DABS data which have been processed. Those channels successfully processed without significant clipping are indicated by an "x" while channels which were partially processed for a station are marked with "o". Blank spaces indicate channels which were not processed.

One common problem that had to be addressed in the Fortran processing stage was clipped data. Channel data which had the overload word flagged (i.e. clipped data) were not used in the spectral estimates. The Fortran software kept track of the total number of clipped records in each spectral estimate (which equates to a total time). If the requested averaging time (1 minute in this case) was clipped for more than a 10% (6 secs) of the time, the entire spectral estimate was discarded and a new ensemble average was started. This eliminated having any averaged spectra spanning an excessively long time period, however it can result in unequal sampling (in time) of the

Table 3. Processed data from the shallow water (NDABS) array.

LEG	EVENT	HYDROPHONE NUMBER																														
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
1	40U	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
1	30U	X	X	X		X	X	X	X	X	X			X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
1	25U	X	X	X	X	X	X	X		X	X			X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
1	20U	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
1	15U	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
1	10U	X	X	X	X	X	X	X		X	X	X		X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
1	15A	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
1	20A	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
1	25A	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
1	35A	X	X	X	X	X	X	X	o	X	X	X	X	X	X	X	o	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
1	40A	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
2	25U	X	X	X	X	X	X	X		X	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
2	25A	X	X	X	X	X	X	X		X	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
3	25.1																																
3	25.2	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		
3	25.3																																

Table 4. Processed data from the deep water (ADABS) array.

LEG	EVENT	HYDROPHONE NUMBER																														
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
1	40U									X		X	X		X	X	X	X	X	X	X	X	X	o	X	X	X	X	X	X	X		
1	30U				o	o	o	o	o	o	o	o	X	o	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
1	25U				X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
1	20U				X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
1	15U				X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
1	10U	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
1	15A																																
1	20A				X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
1	25A									X	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
1	35A	o	o	o	o	o	o	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
1	40A							X	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
2	25U	ARRAY NOT DEPLOYED																															
2	25A				o	o	o	o	o	X	o	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
3	25.1																																
3	25.2					o	o	o	o	X	o	X	X	X	X	X	o	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
3	25.3																																

processed propagation data.

Waterfall plots of averaged spectra versus time clearly show the presence or absence of the signal data (Figure 15a and 15b). Acoustic pressures for signals at 150, 400, 800, and 1600 Hz and noise at 160, 410, 810, and 1610 Hz were determined from

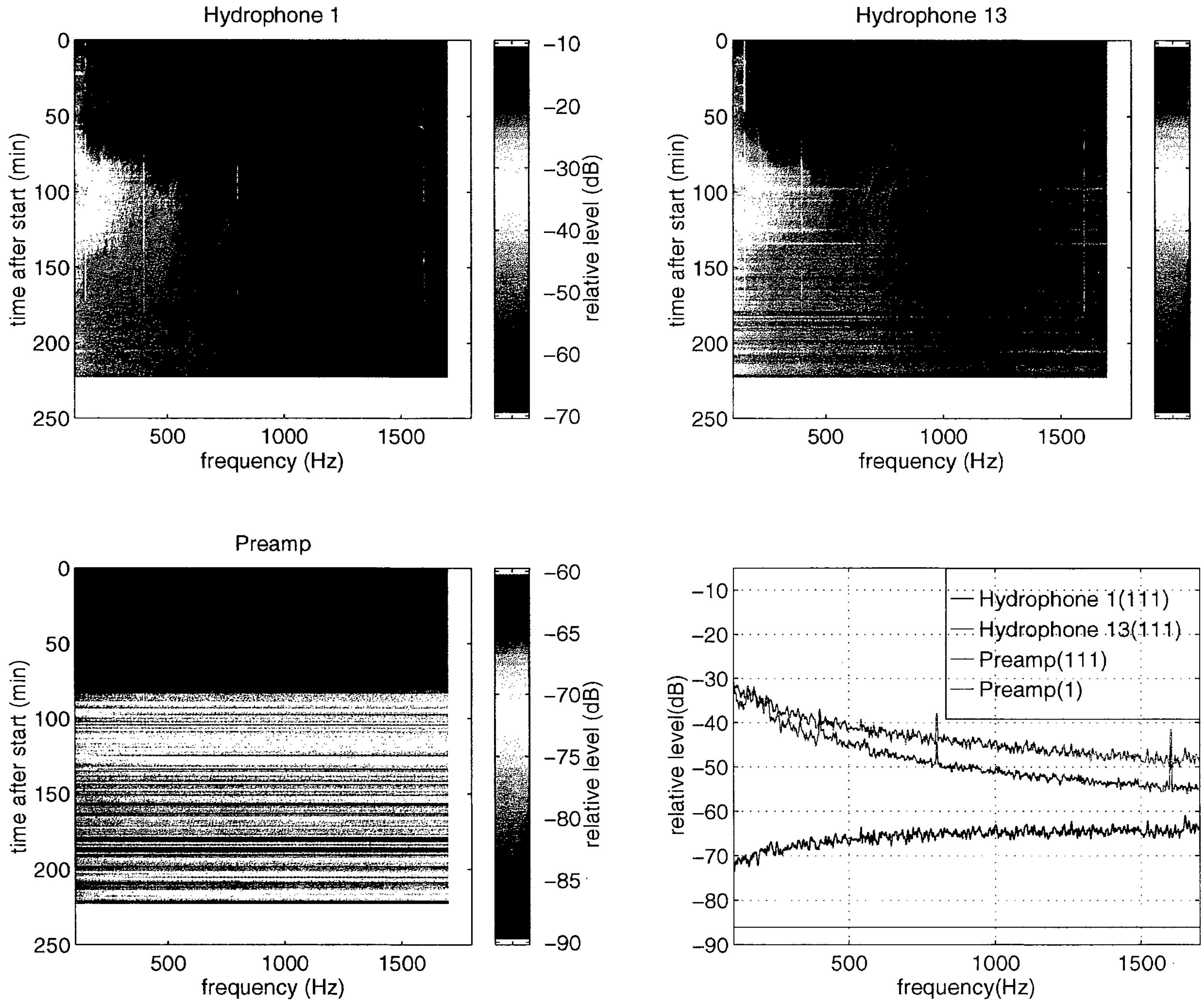


Figure 15. (a), (b), and (c) are grams from the shallow water (NDABS) array during Leg 1 Station 30U. (d) shows individual spectra from 2 channels and the preamp.

processed data and placed into separate signal and noise data bases. Signal data bases were edited based on frequency and signal-to-noise ratios (S/N); signal and noise levels were obtained through equation 1, i.e. noise levels were not corrected for processing bandwidth for this portion of the analysis. Frequency editing was done whenever the reported signal level was chosen from a frequency bin other than the signal frequency bin. Two criteria were used for S/N editing; (1) an average S/N calculated over a sliding window of data points and (2) individual S/N ratios calculated for each data point. Each acoustic data point represents approximately a 1 minute average. A running mean of S/N was calculated over 6 points and assigned to the data point at the center of each averaging window. The window was advanced one data point and the average S/N was recalculated over this new data window. This new average was assigned to the data point at the center of this new averaging window. Data points having an average S/N less than 5 dB were removed from the data base. In order to preserve some detailed structure of TL fluctuations with range, data points which had an average S/N > 5 dB but individual S/N between 3 and 5 dB were kept, that is, deeper nulls in the signal data with a signal still obviously present and S/N >3 dB were retained in the data base. These points reflect the ability to detect the signal and give a more realistic representation of the transmission loss (TL) structure but may not give the accurate signal amplitude. Figure 16 shows a typical editing result for this data set.

Absolute levels for signal (SL) and noise (NL) were obtained by equation 2,

$$SPL_{abs} = SL_a - SG - HS - 10 \log (BW) \qquad (2)$$

where SPL_{abs} = absolute sound pressure level, SL_a = raw spectrum level, SG=system gain, HS = hydrophone sensitivity, and BW = processing bandwidth (for noise data only).

Reported source levels for the projector (see Source and Signals section) were applied to received level data from all events according to equation 3;

$$TL = SL - SPL_{abs} \qquad (3)$$

where TL=transmission loss (dB re 1 μPa/m), and SL=source level (dB re 1 m).

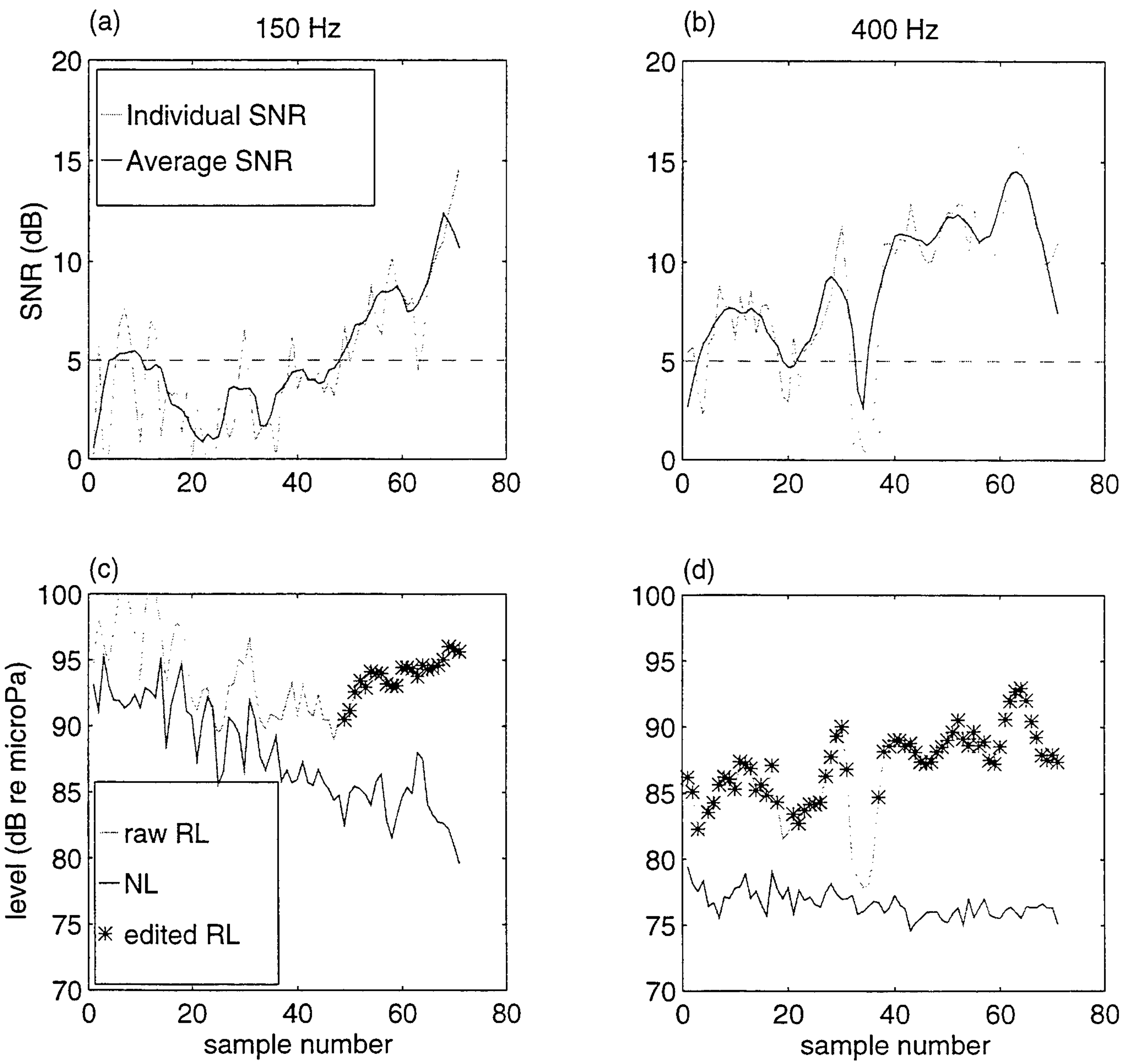


Figure 16. Editing example from ADABS Leg 1 40U for 150 and 400 Hz. (a) and (b) show comparisons of SNR ratios while (c) and (d) show the acoustic levels of the raw and edited data.

Data Quality

Data quality was determined by;

- extent of clipping observed during a processing run,
- examining preamp data from both DABS systems to evaluate system noise,
- studying signal and noise depth dependence to determine (1) phone to phone variability , and (2) the array's sensitivity to flow noise or surface noise,
- comparing TL and noise depth dependence plots to evaluate each stations overall caliber.

The first indicator of overall data quality comes from log files produced during the FFT processing stage. These files record the number of times the FFT had to be restarted due to excessive clipping and the channels on which this clipping occurred. When clipping is extensive on any particular channel, processing is stopped so the user can eliminate this channel and proceed.

The NDABS system developed a salt water leak in the array connector during the first deployment. This salt water leak effected the data from recording channels 8-16 (50-90 m hydrophone depth) throughout leg 1. At 160 Hz, ambient noise levels were from 4 to 8 dB higher on these channels than ambient noise levels from the rest of the array (see Appendix A). At higher frequencies (410, 810, and 1610 Hz) ambient noise levels were usually 1 to 1.5 dB lower than the rest of the array. These effects can also be detected in the TL depth dependence plots once the analyst is aware of the problem (see Appendix A). This leak resulted in the loss of data from channels 8, 11, 12, and 16 during portions of the upslope stations, most noticably during station 25U. Channels 11 and 12 became active again during the along slope transects. Effects of the leak in terms of higher than normal system noise were detected on the preamp during stations 30U (Figure 15) and 25U. Finally, data from the third group of channels (17-24) had higher than normal noise levels during stations 40U across the recording bandwidth. The accuracy of both signal and noise levels from channels 8 through 16 for leg 1 are suspect due to this leak. This leak was detected and fixed by system engineers during the recovery between legs 1 and 2. Although channels 8 and 16 remained impaired, all other channels functioned normally during the remainder of the exercise. Channels 8

and 16 were switched with channels 31 and 32 prior to leg 3 of the exercise. This resulted in the loss of the two deepest "hydrophones" during leg 3, one of which was the system preamp.

Clipping was a common nuisance on the ADABS system and resulted in a significant loss of data. The shallowest three phones in the ADABS system continually had clipped levels and little data was recoverable from these receivers. During leg 1 stations 40U and 30U, leg 2 station 25a, and leg 3 station 25II, data was also clipped on other phones as well (see Table 4).

The most common cause of poor transmission loss data was due to high noise levels from shipping activity, particularly at frequencies < 500 Hz. Ambient noise levels were depth independent across both acoustic arrays (see noise plots in Appendix A). High noise levels resulted in a loss of data during leg 1 station 30U and 40A, leg 2 upslope stations I, II, and III, and leg 3 station 25 II at all source frequencies. This is readily seen in the mid water depth hydrophone waterfall plots from these stations (Figures 17 and 18) and the signal and noise depth dependence plots (Appendix A). The noise level appears higher and more sporadic at the shallower NDABS site, while the noise is lower in level but more persistent and therefore often presents a problem in data processing at the deep water ADABS site.

When ambient noise and propagation conditions were favorable, the data quality of the 400, 800 and 1600 Hz source frequencies were excellent. The 150 Hz source line was more difficult to detect than higher frequency lines due to low frequency shipping noise and at times, the FM source. Table 5 indicates the percentage of reliable data per station and frequency for both systems. Percentages are normalized to the number of spectra produced during the NDABS processing of each station and are based on 32 channels for each array. ADABS typically had fewer spectra than NDABS with the exception of leg 1 stations 25U and 20U, when the salt water leak in the array connector severely effected the NDABS data. The reported percentages reflect this. For example, during station 40U, NDABS had reliable TL values from approximately 26% of the total processed spectra (175), or 45 spectra (175*(~.26)=45), while ADABS had approximately19% or 33 spectra. During station 25U NDABS had approximately 55% or 46 spectra while ADABS had 116% or 101 spectra. Again, these

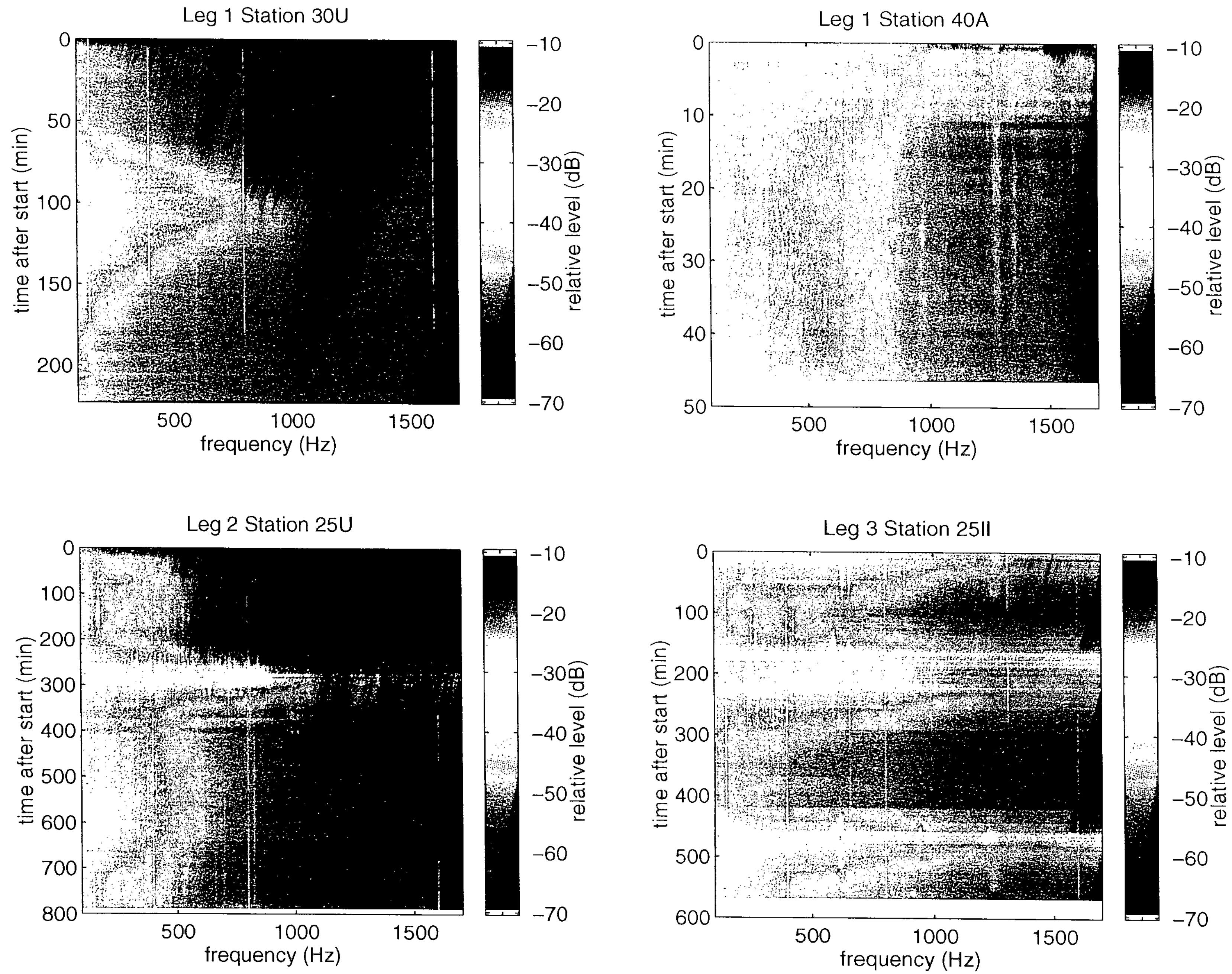


Figure 17. Grams from shallow water NDABS array during high noise level periods.

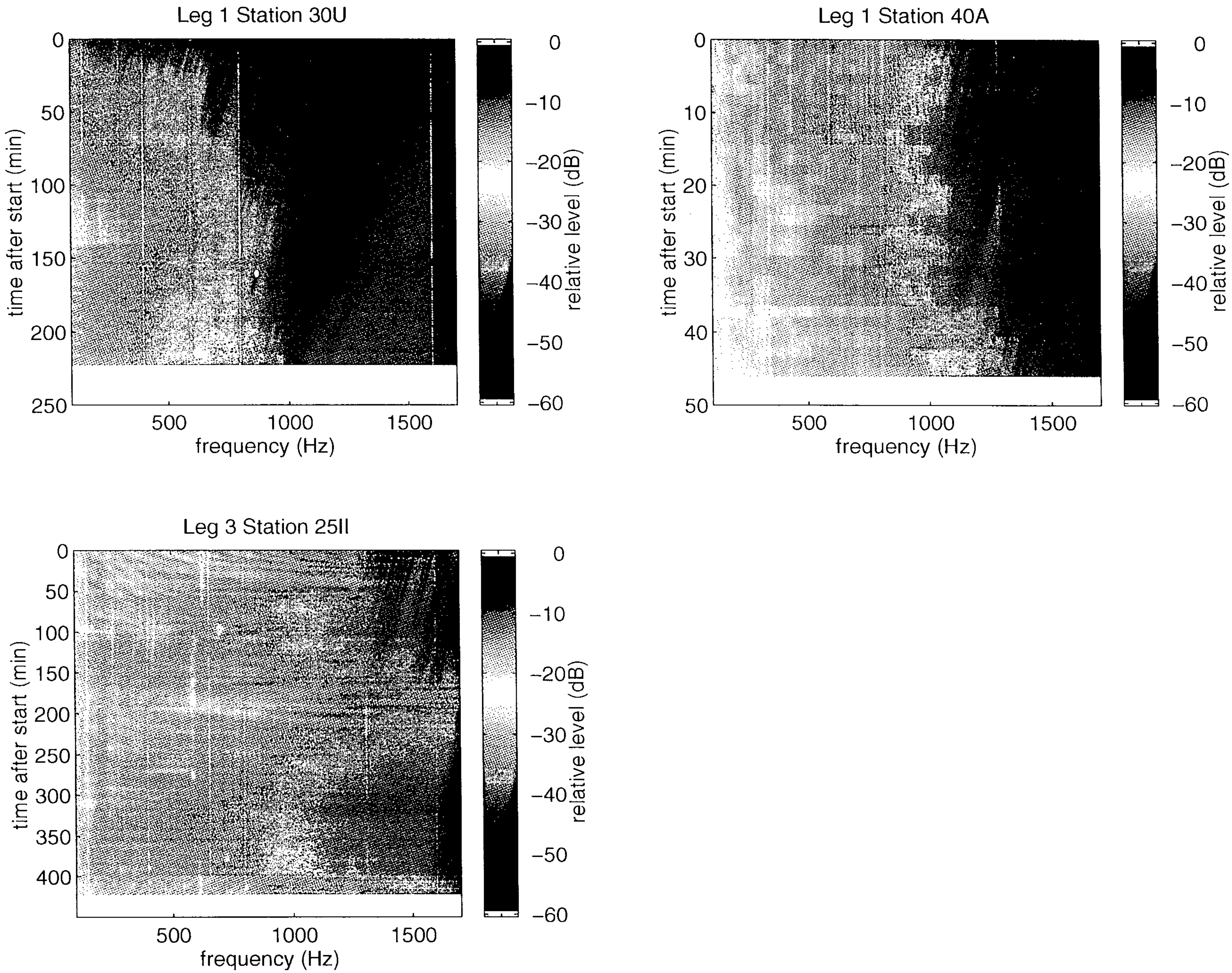


Figure 18. Grams from deep water ADABS array during high noise level periods.

percentages are normalized to the NDABS processing results so stations where ADABS had more spectra can have over 100% of the number of spectra/channel.

Table 5. Data quality is defined as the percentage of edited data points versus total number of possible spectra resulting from each NDABS processing run. Percentages are given for NDABS first, then ADABS, with a '/' separating the two.

LEG	STATION	SPECTRA/CH	150 Hz	400 Hz	800 Hz	1600 Hz
1	40U	175	26/19	67/64	66/61	77/69
1	30U	197	39/22	52/39	66/40	72/41
1	25U	87	55/116	54/126	46/125	49/126
1	20U	109	64/85	69/88	62/88	83/91
1	15U	109	66/85	73/83	75/83	91/85
1	10U	89	56/NA	65/NA	64/NA	65/NA
1	15A	82	81/77	82/68	83/71	84/70
1	20A	119	67/51	75/57	76/55	61/42
1	25A	65	95/62	85/56	74/55	61/43
1	35A	125	68/56	46/35	47/24	31/28
1	40A	46	10 and 1	5 and 9	6 and 10	10 and 22
2	25U	906	19/NA	32/NA	51/NA	53/NA
2	25A	1405	83/38	84/39	85/39	84/37
3	25 II	443	63/29	51/24	44/22	44/20

Both range and source depths changed during the course of leg 1. The stations of leg 1 generally had good propagation data. The exceptions to this are the 150 Hz source line, which appears effected by the FM source and ship radiated noise, station 40A which had sustained high ambient noise levels, and data from the shallow array during the 20 m source depth portion of the upslope stations.

Leg 2 consisted of two 24 hour segments where the source remained at the 50 m depth. Only the shallow water (NDABS) array was deployed for the upslope station before severe weather set in. The upslope station had poorer quality data due to higher noise levels, presumably from the very rough weather conditions. TL data at

source frequencies of 800 and 1600 Hz are of acceptable quality and quantity for further analysis. Weather conditions had improved prior to the second portion of leg 2 which permitted deployment of the deep water array (ADABS). High quality data is available from both systems at all frequencies during the along slope station. The source ship drifted close to the receiver arrays (Figure 8) and this change in range resulted in higher received levels of both signal and ship radiated noise (below 200 Hz). Ship radiated noise appears to be higher once the ship presented a stern aspect to the receiver arrays. This noise was of low enough level that it did not affect the propagation data.

Calm weather conditions during leg 3 permitted local fisherman to operate in the area. The resulting acoustic data is often contaminated by shipping noise across the recording bandwidth of both systems (Figures 17d and 18c). However, this long duration event (~9 hours) provided some opportunity to collect continuous propagation data of up to 3 hours duration from the shallow water system (see Appendix A). The longer source-receiver distances and corresponding increased transmission loss combined with noisy condtions resulted in significantly less data from the deep water array.

ACKNOWLEDGMENTS

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[4] USRD Calibration Memorandum No. 9603, Underwater Sound Reference Detachment, Naval Research Laboratory, Orlando FL (06 Feb 1992).

[5] USRD Calibration Memorandum No. 9582, Underwater Sound Reference Detachment, Naval Research Laboratory, Orlando FL (03 Dec 1991).

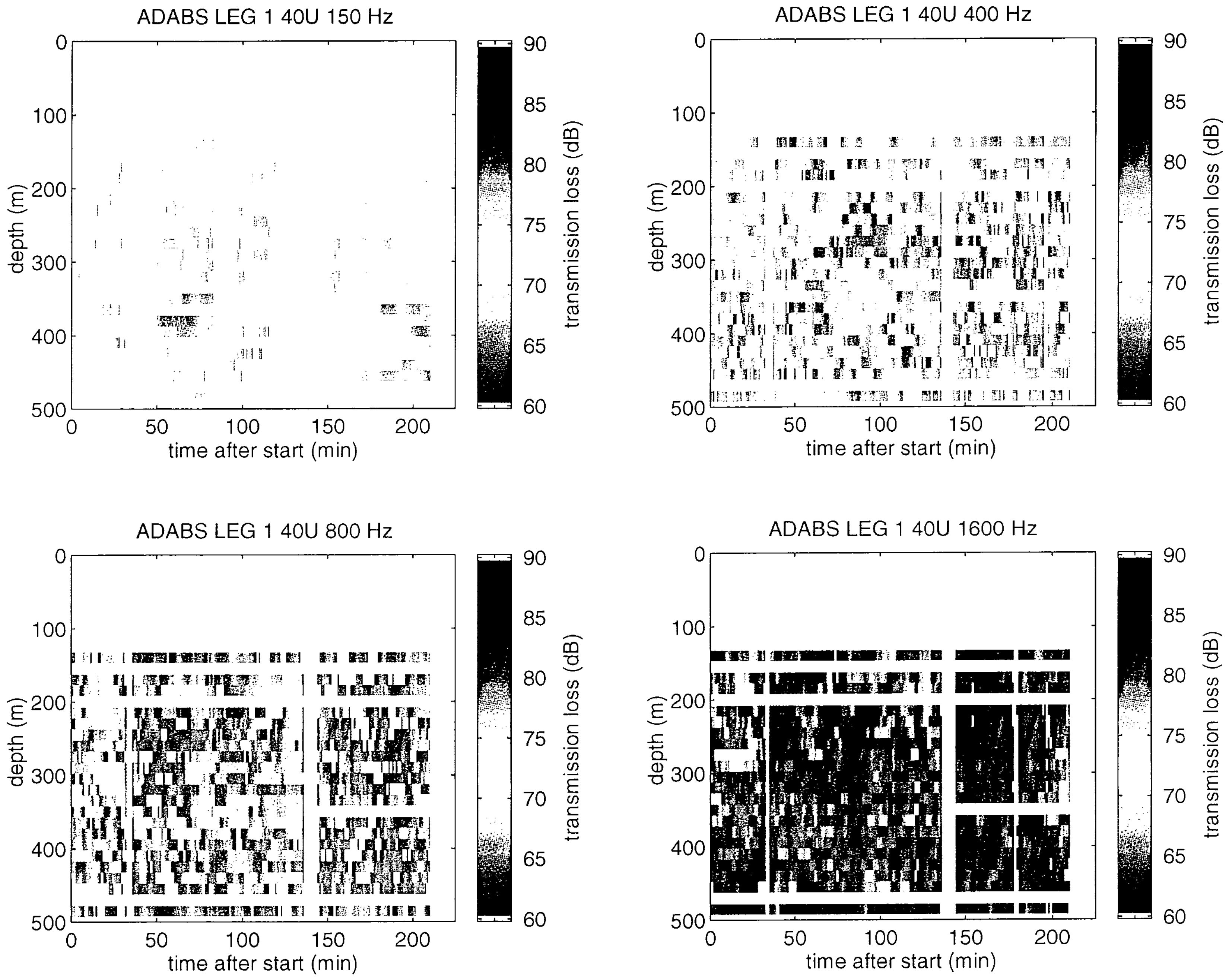
[6] USRD Calibration Memorandum No. 9221, Underwater Sound Reference Detachment, Naval Research Laboratory, Orlando FL (02 Nov 1990).

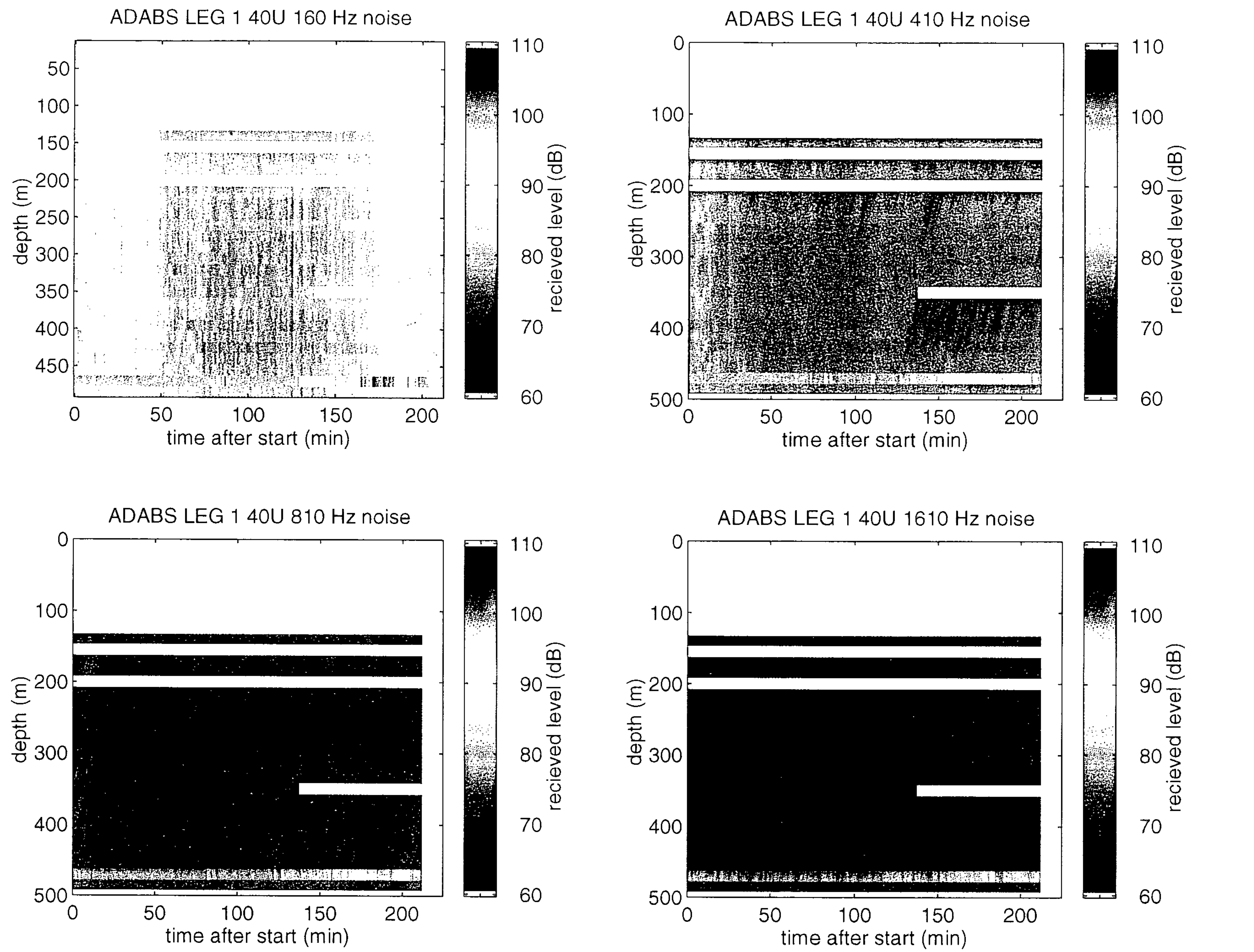
APPENDIX A
DEPTH DEPENDENCE PLOTS

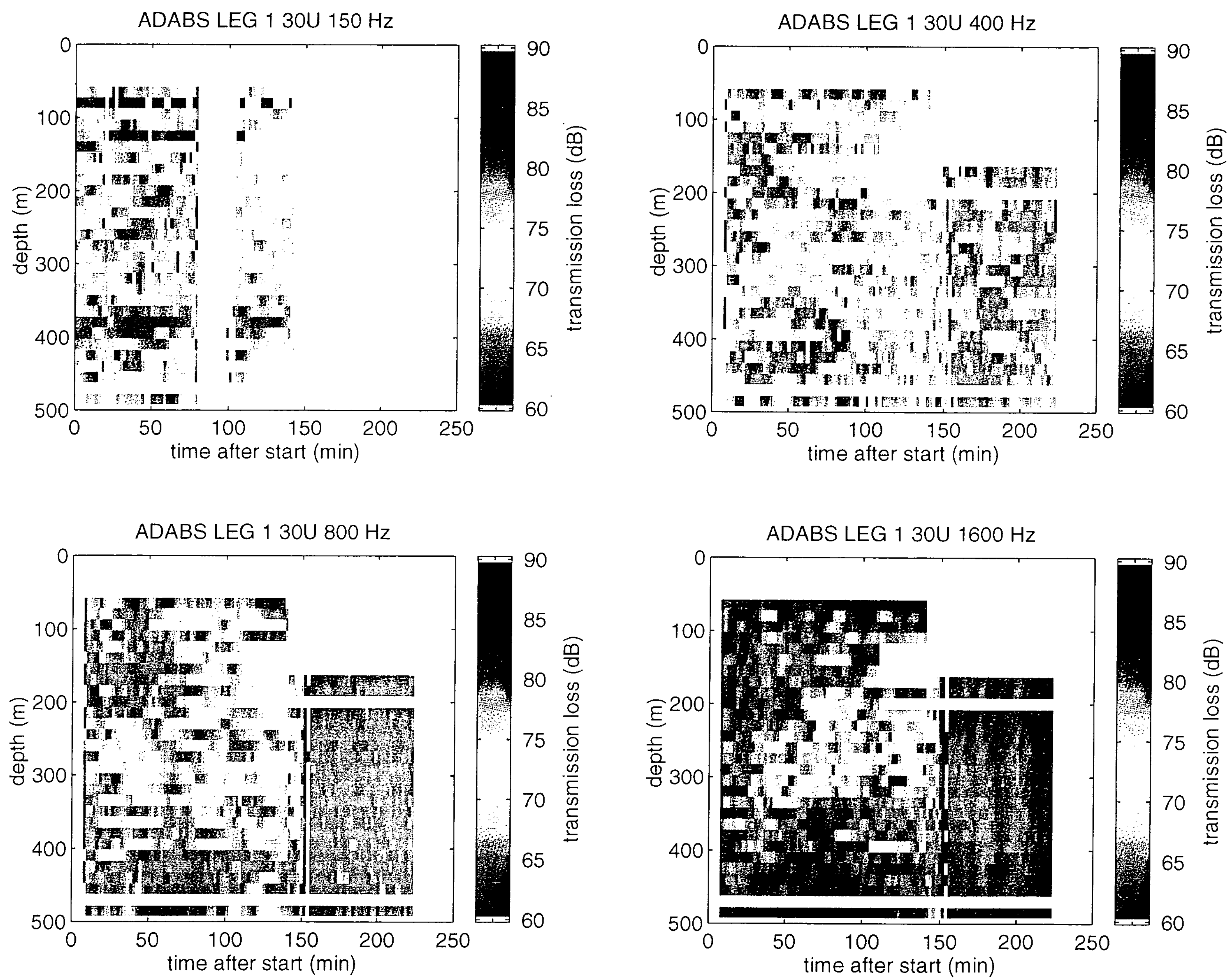
Depth dependence plots of both transmission loss and ambient noise levels are included for each processed station from SESAME I. With very few exceptions a 30 dB range was used for TL color scales and a 50 dB scale was used for ambient noise plots. Therefore, the user can compare TL and noise levels across stations and array locations. Reported TL spectrum levels are in dB re 1 μPa while noise spectrum levels have been corrected for the processing bandwidth and have units of dB re 1 $\mu Pa^2/Hz$ (see Data Processing section for details).

One plot per station and frequency is shown in the appendix. These plots are annotated with time after start and include all processed data from each station. Source depth changes during leg 1 are readily apparent in the 150 Hz plots. During many of the stations, the signal level was very low during the 20 m source depth transmissions, particularly at 150 Hz.

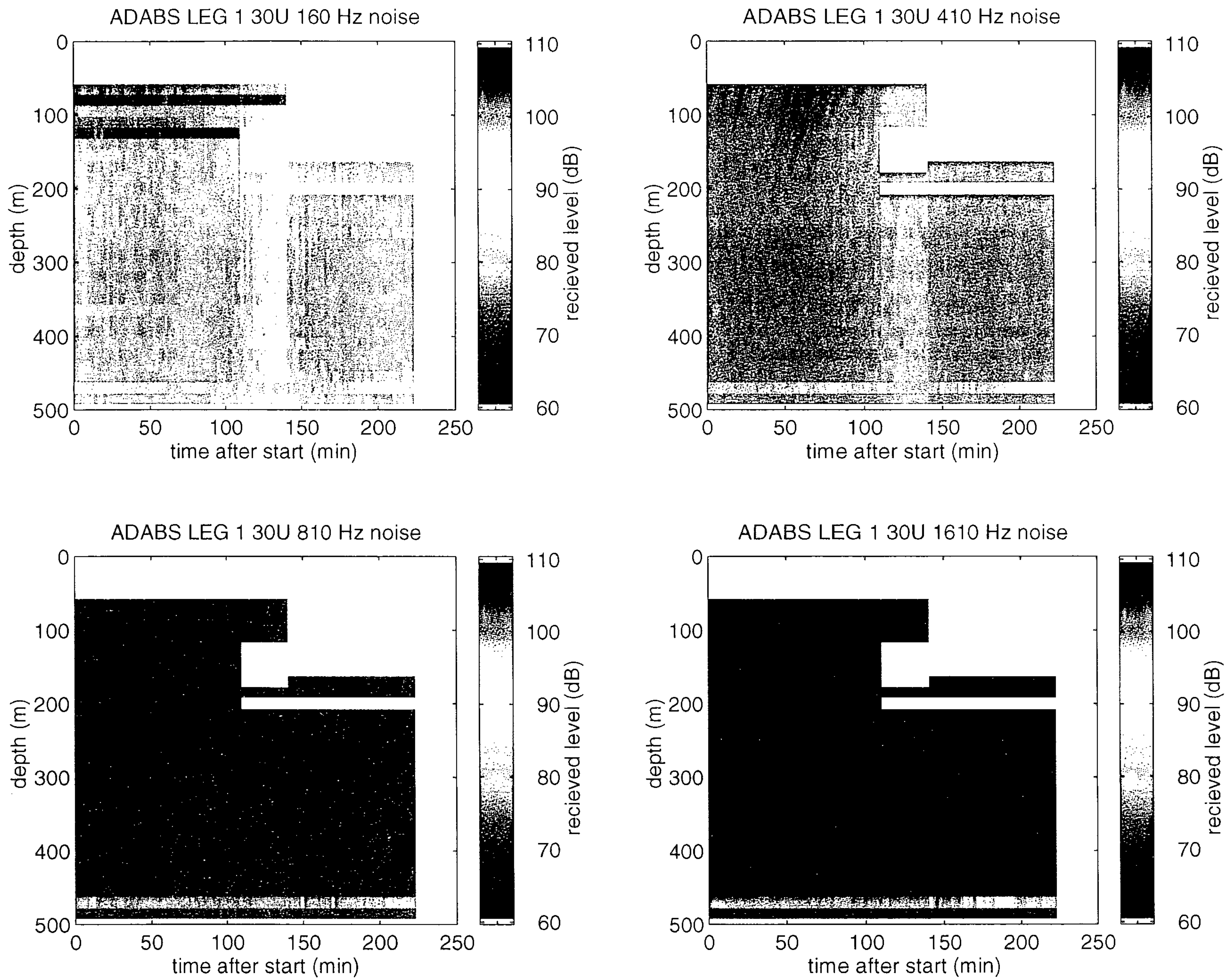
Plots were produced using MATLAB's *imagesc* subroutine which assumes equally spaced two dimensional data and plots accordingly. This means that uneven hydrophone spacing or unequal time sampling is not fairly represented and the image may be distorted. This is particularly noticable in plots for the deep water array where hydrophone spacing for the deeper phones was different than the hydrophone spacing for the shallow phones. The colorbar convention in MATLAB resulted in the system noise values from the preamp being plotted, usually as a single color which shows up as a stripe close to the bottom of the ambient noise plots. The color assigned to the system preamp does <u>not</u> correspond to the colorbar at the right hand side of the plot and should be ignored (see Calibrations section for a discussion of system noise levels).


ADABS LEG 1 40U 150 Hz
ADABS LEG 1 40U 400 Hz
ADABS LEG 1 40U 800 Hz
ADABS LEG 1 40U 1600 Hz
depth (m)
time after start (min)
transmission loss (dB)

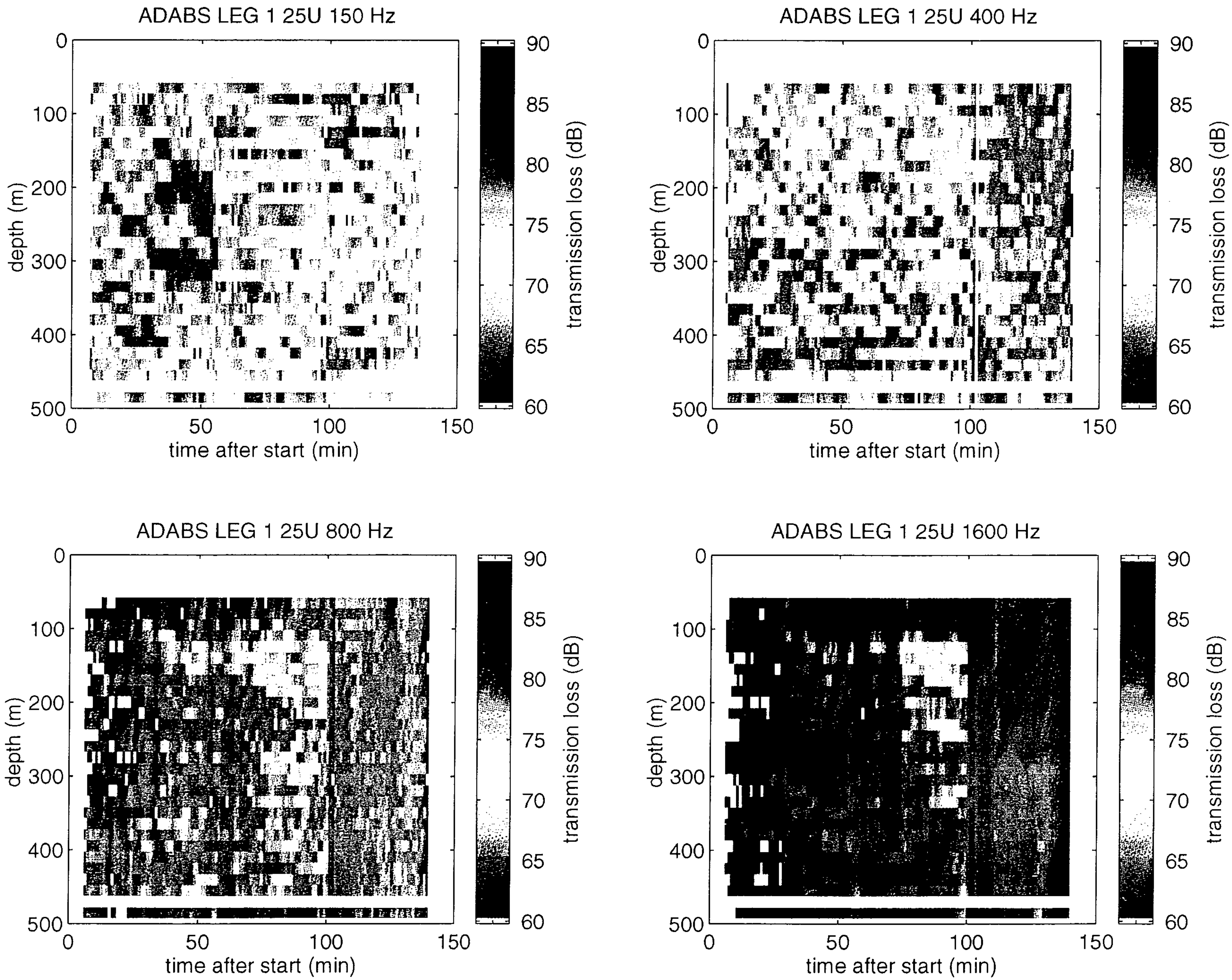

ADABS LEG 1 40U 160 Hz noise
ADABS LEG 1 40U 410 Hz noise
ADABS LEG 1 40U 810 Hz noise
ADABS LEG 1 40U 1610 Hz noise
depth (m)
time after start (min)
recieved level (dB)

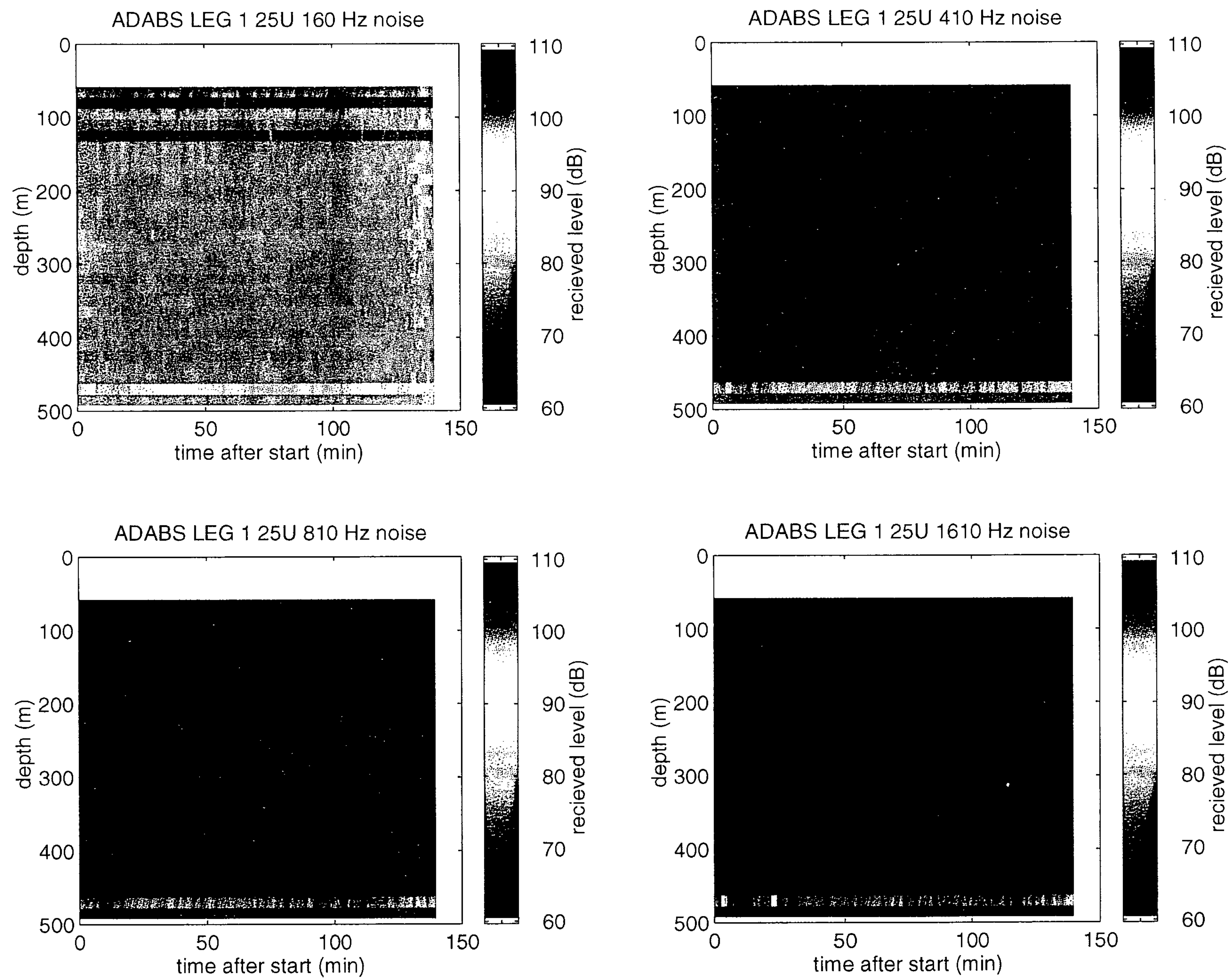


ADABS LEG 1 30U 150 Hz
ADABS LEG 1 30U 400 Hz
ADABS LEG 1 30U 800 Hz
ADABS LEG 1 30U 1600 Hz
depth (m)
time after start (min)
transmission loss (dB)

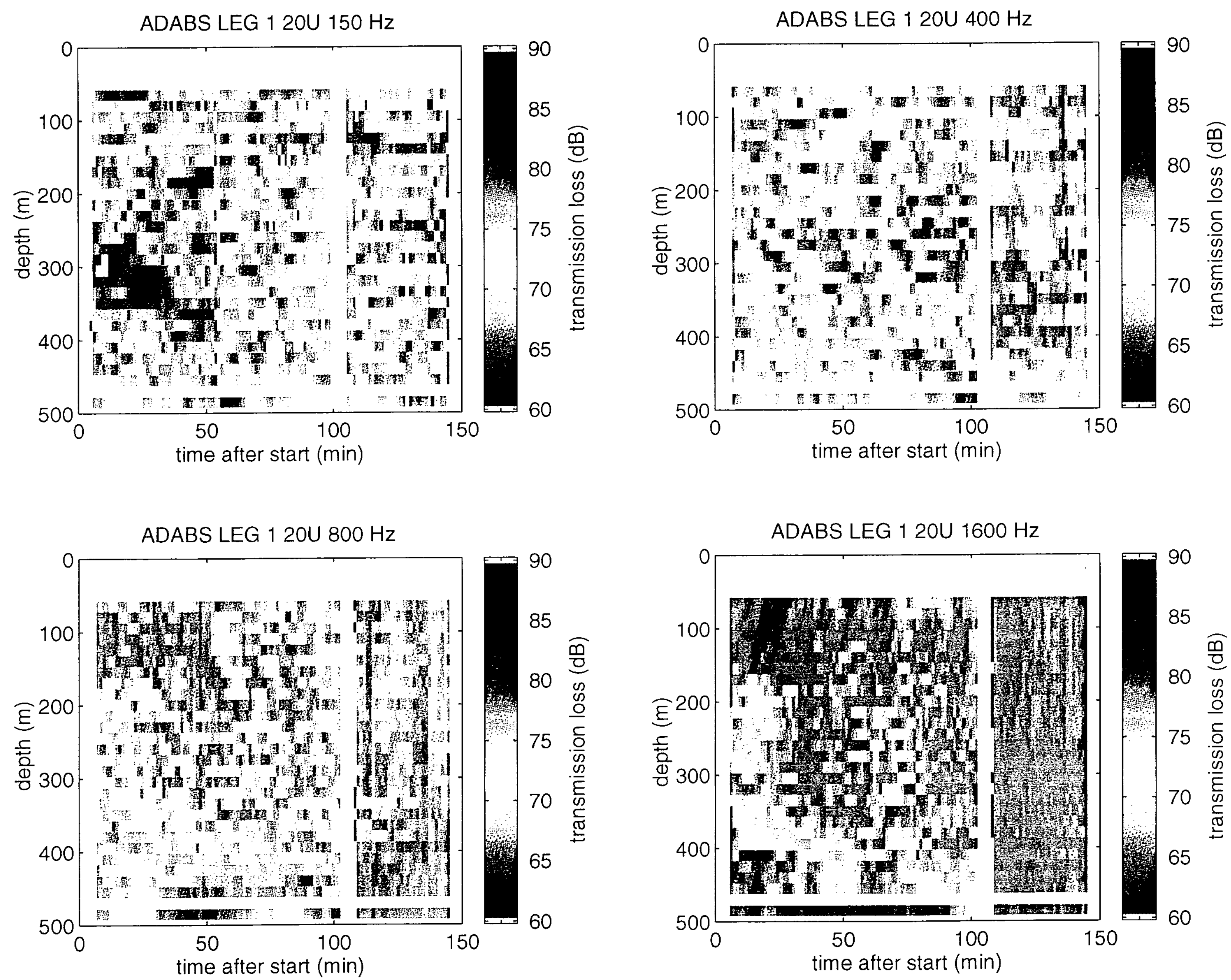


ADABS LEG 1 30U 160 Hz noise
ADABS LEG 1 30U 410 Hz noise
ADABS LEG 1 30U 810 Hz noise
ADABS LEG 1 30U 1610 Hz noise
depth (m)
time after start (min)
recieved level (dB)
0
100
200
300
400
500
50
150
250
60
70
80
90
110

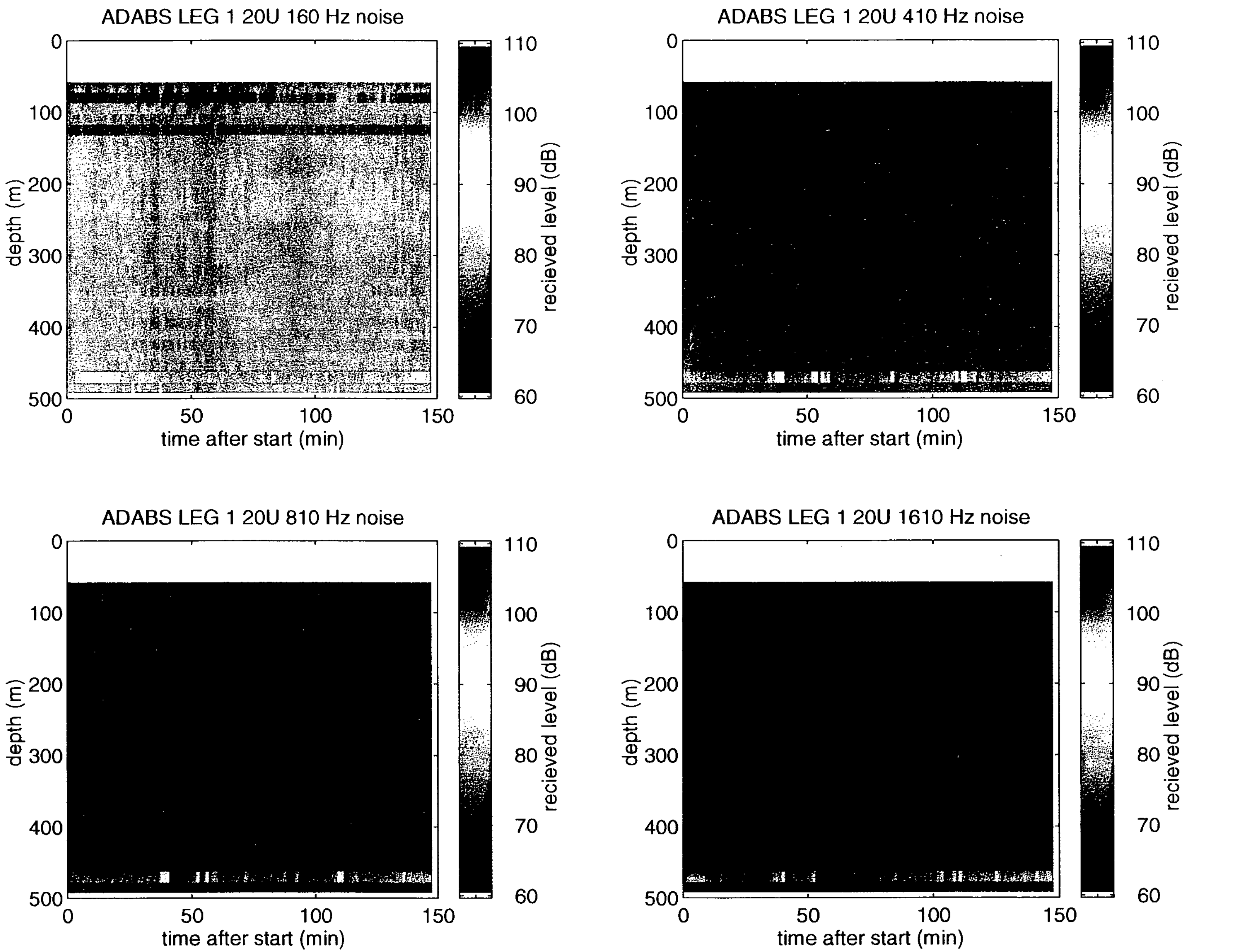

ADABS LEG 1 25U 150 Hz
ADABS LEG 1 25U 400 Hz
ADABS LEG 1 25U 800 Hz
ADABS LEG 1 25U 1600 Hz
depth (m)
time after start (min)
transmission loss (dB)
0
100
200
300
400
500
50
150
60
65
70
75
80
85
90

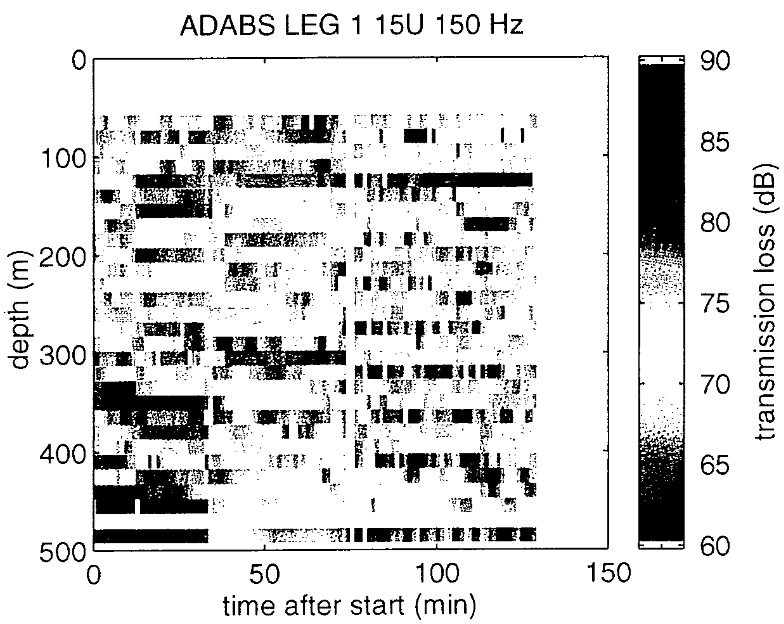


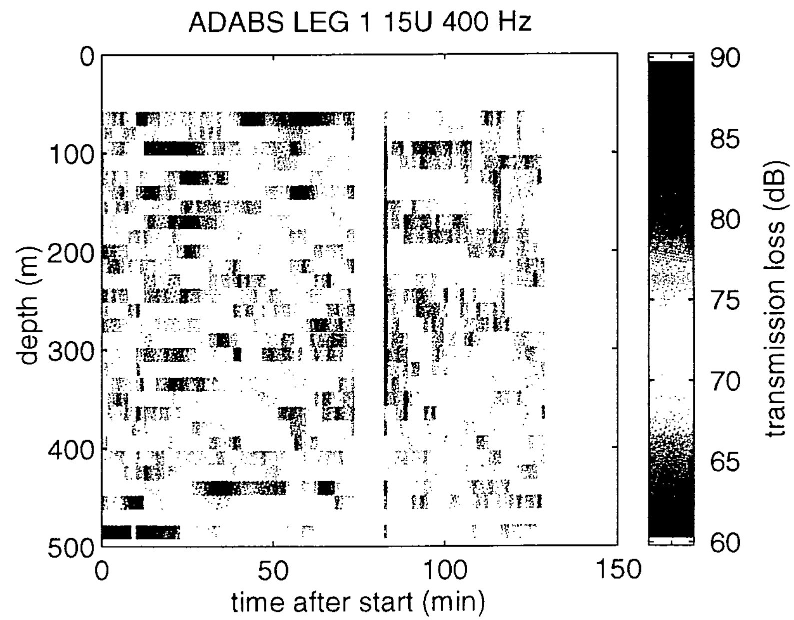
ADABS LEG 1 25U 160 Hz noise
ADABS LEG 1 25U 410 Hz noise
ADABS LEG 1 25U 810 Hz noise
ADABS LEG 1 25U 1610 Hz noise
depth (m)
time after start (min)
recieved level (dB)

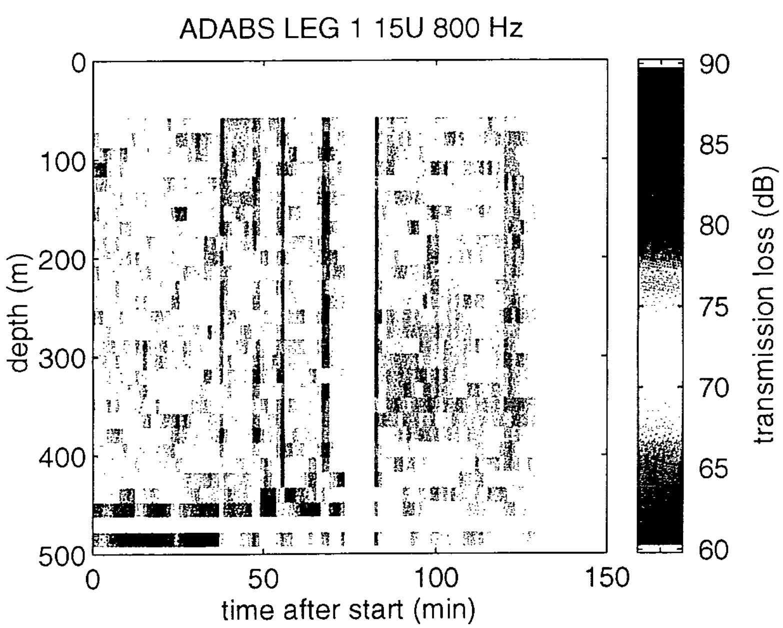


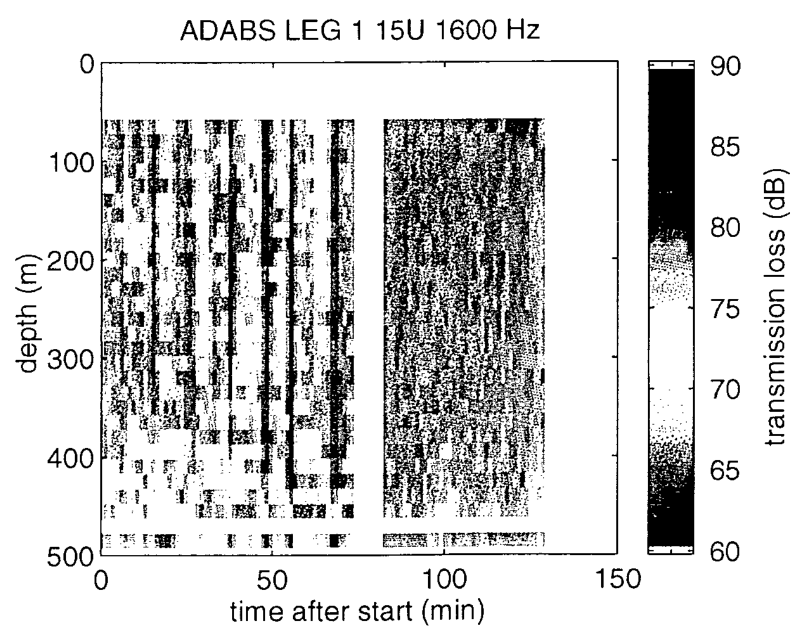
ADABS LEG 1 20U 150 Hz
ADABS LEG 1 20U 400 Hz
ADABS LEG 1 20U 800 Hz
ADABS LEG 1 20U 1600 Hz
depth (m)
time after start (min)
transmission loss (dB)

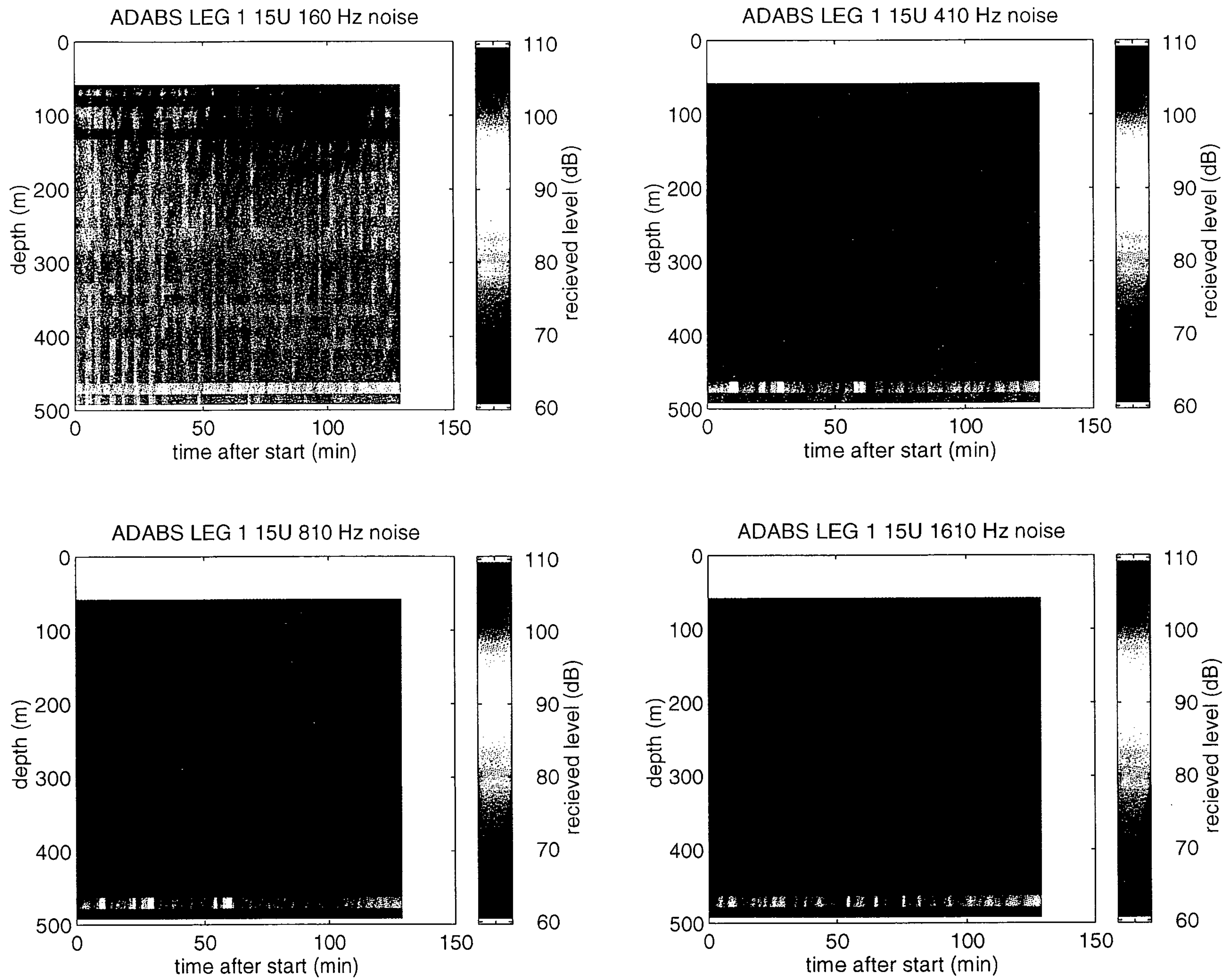

ADABS LEG 1 20U 160 Hz noise
ADABS LEG 1 20U 410 Hz noise
ADABS LEG 1 20U 810 Hz noise
ADABS LEG 1 20U 1610 Hz noise
depth (m)
time after start (min)
recieved level (dB)
0
100
200
300
400
500
50
150
60
70
80
90
110

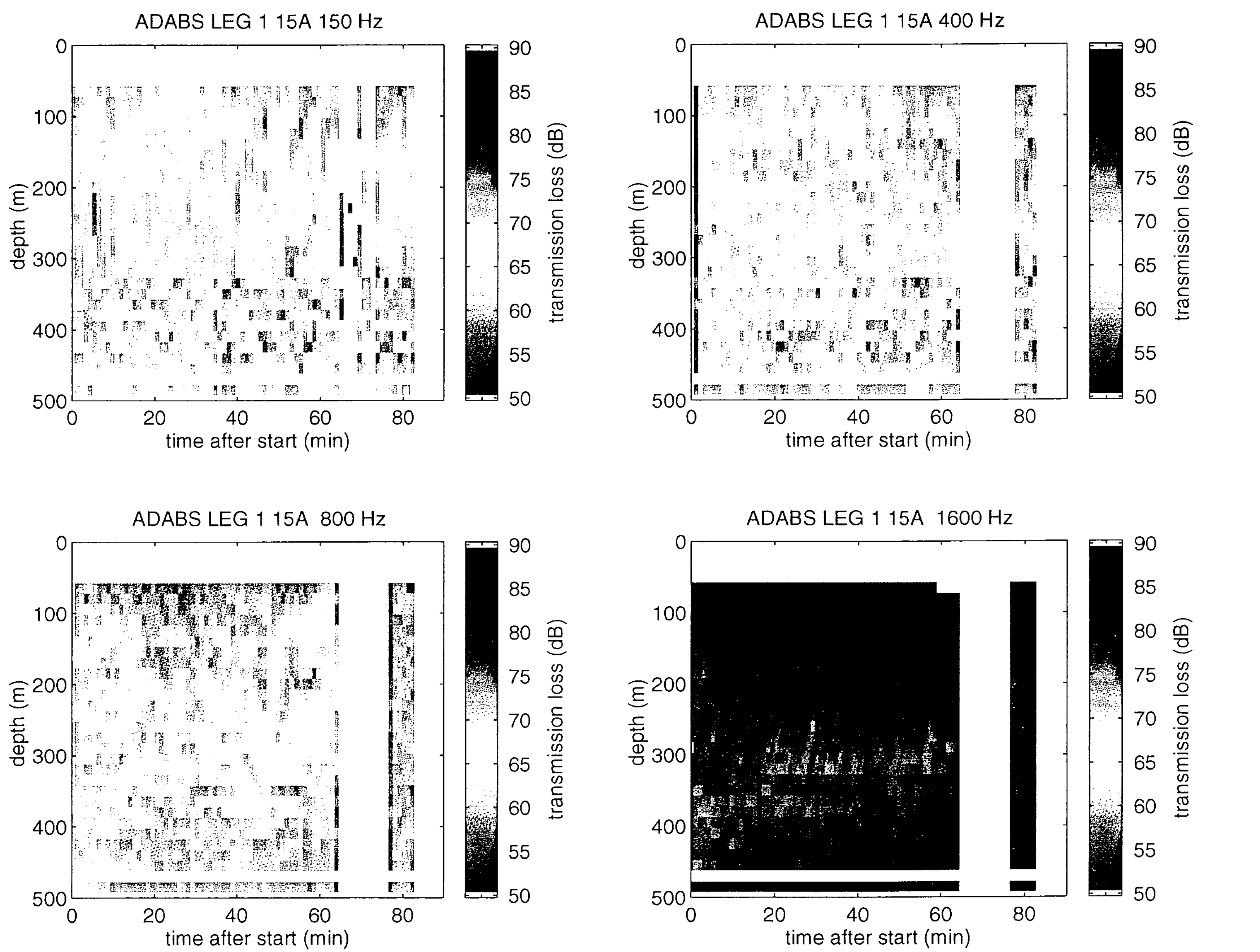

ADABS LEG 1 15U 150 Hz
depth (m)
time after start (min)
transmission loss (dB)

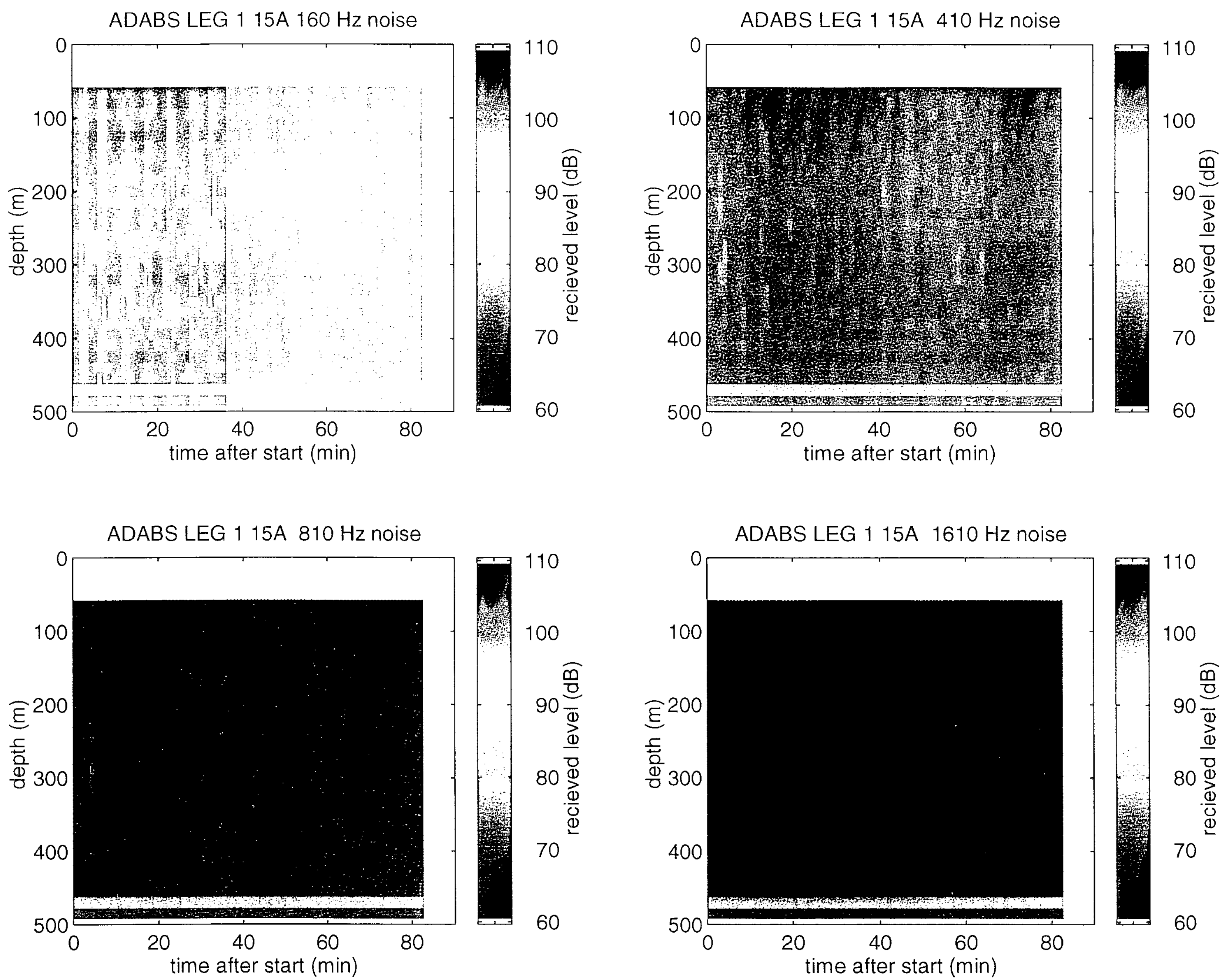

ADABS LEG 1 15U 400 Hz
depth (m)
time after start (min)
transmission loss (dB)

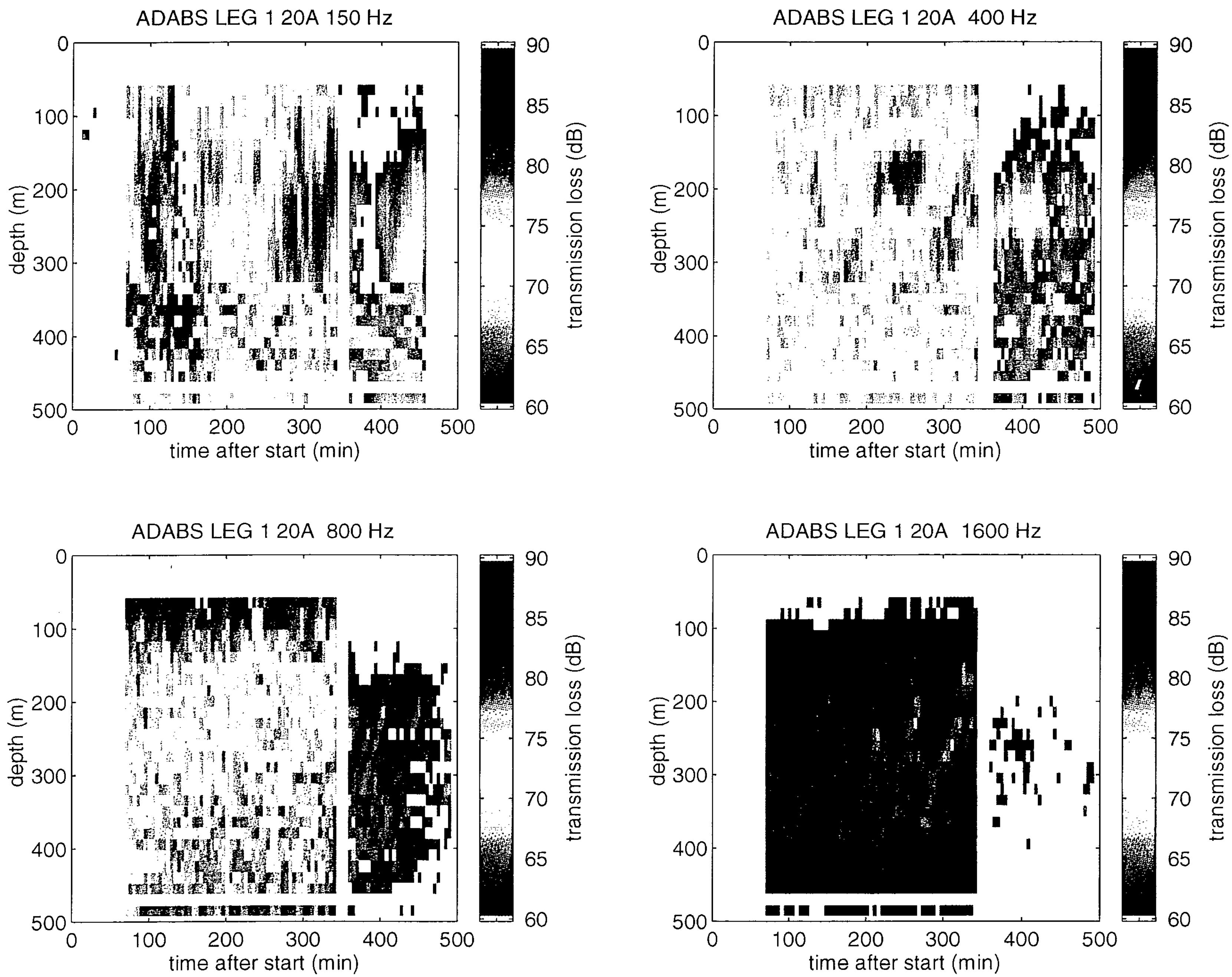

ADABS LEG 1 15U 800 Hz
depth (m)
time after start (min)
transmission loss (dB)

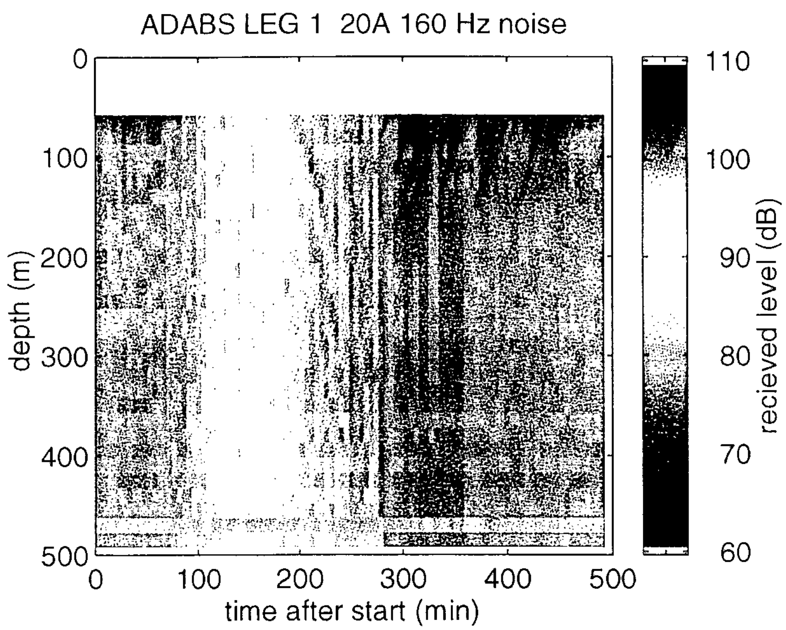

ADABS LEG 1 15U 1600 Hz
depth (m)
time after start (min)
transmission loss (dB)

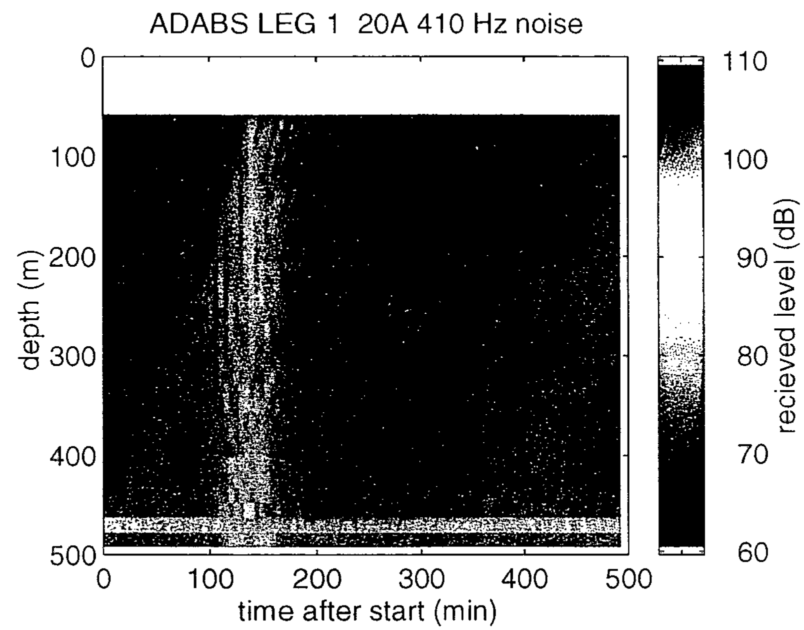

ADABS LEG 1 15U 160 Hz noise
ADABS LEG 1 15U 410 Hz noise
ADABS LEG 1 15U 810 Hz noise
ADABS LEG 1 15U 1610 Hz noise
depth (m)
time after start (min)
recieved level (dB)
0
100
200
300
400
500
50
150
110
90
80
70
60

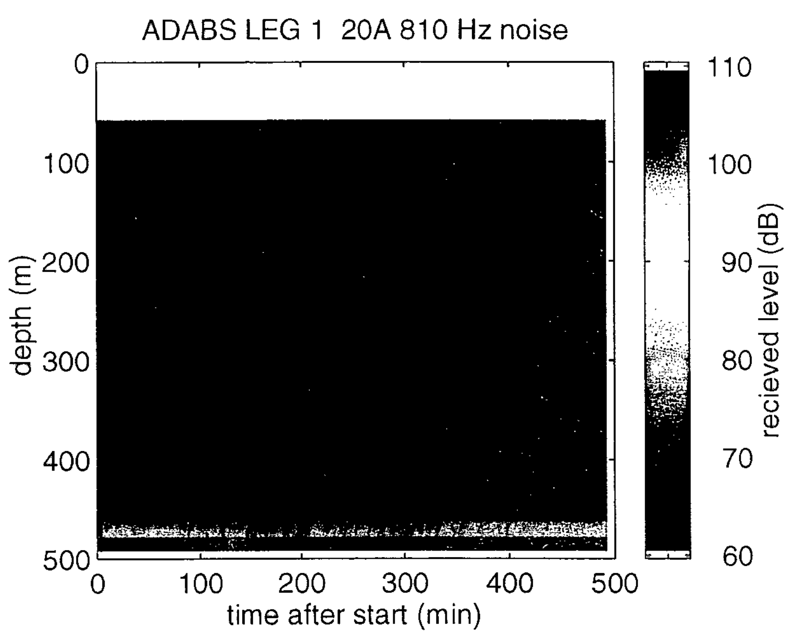

ADABS LEG 1 15A 150 Hz
ADABS LEG 1 15A 400 Hz
ADABS LEG 1 15A 800 Hz
ADABS LEG 1 15A 1600 Hz
depth (m)
time after start (min)
transmission loss (dB)
0
100
200
300
400
500
20
40
60
80
50
55
60
65
70
75
80
85
90

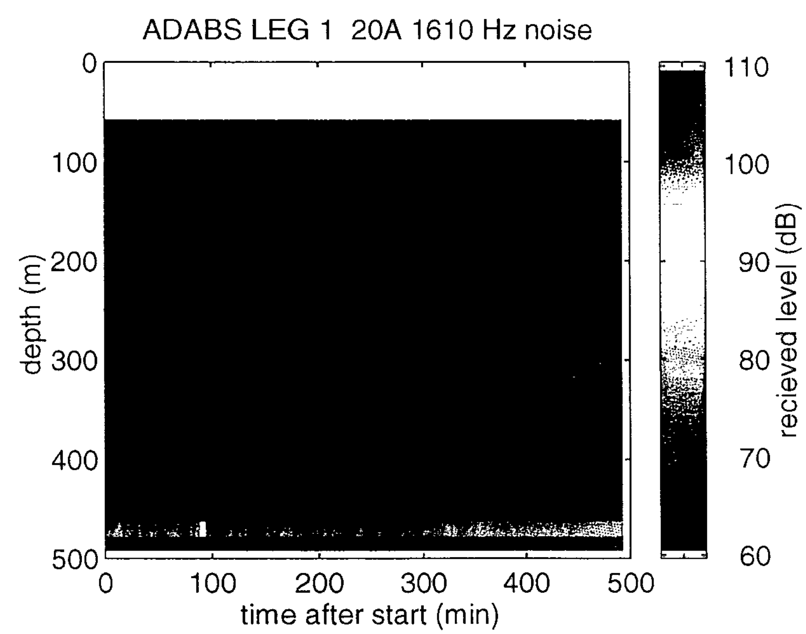

ADABS LEG 1 15A 160 Hz noise
ADABS LEG 1 15A 410 Hz noise
ADABS LEG 1 15A 810 Hz noise
ADABS LEG 1 15A 1610 Hz noise
depth (m)
time after start (min)
recieved level (dB)
0
100
200
300
400
500
0
20
40
60
80
110
100
90
80
70
60

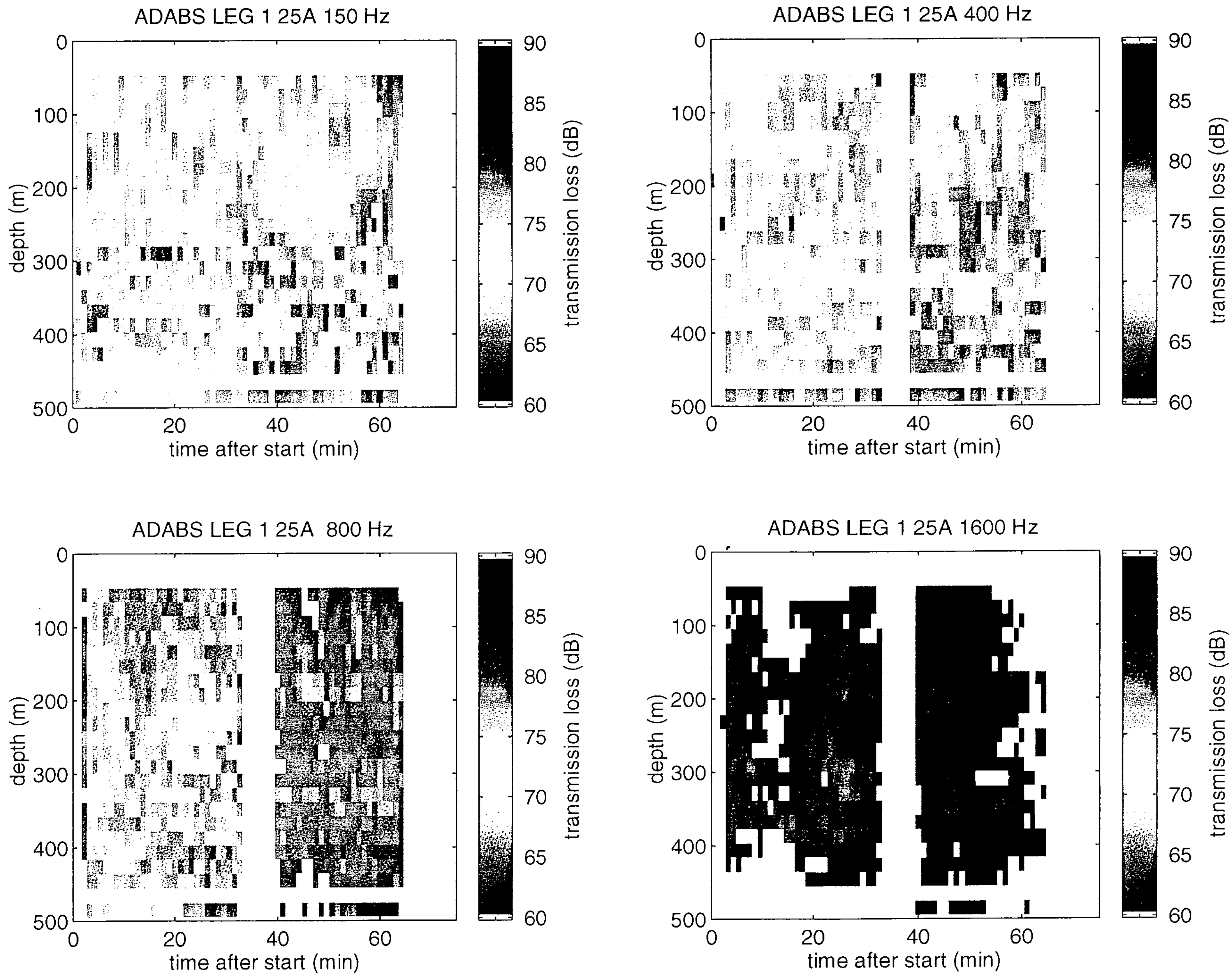

ADABS LEG 1 20A 150 Hz
ADABS LEG 1 20A 400 Hz
ADABS LEG 1 20A 800 Hz
ADABS LEG 1 20A 1600 Hz
depth (m)
time after start (min)
transmission loss (dB)
0
100
200
300
400
500
60
65
70
75
80
85
90


ADABS LEG 1 20A 160 Hz noise
depth (m)
time after start (min)
recieved level (dB)

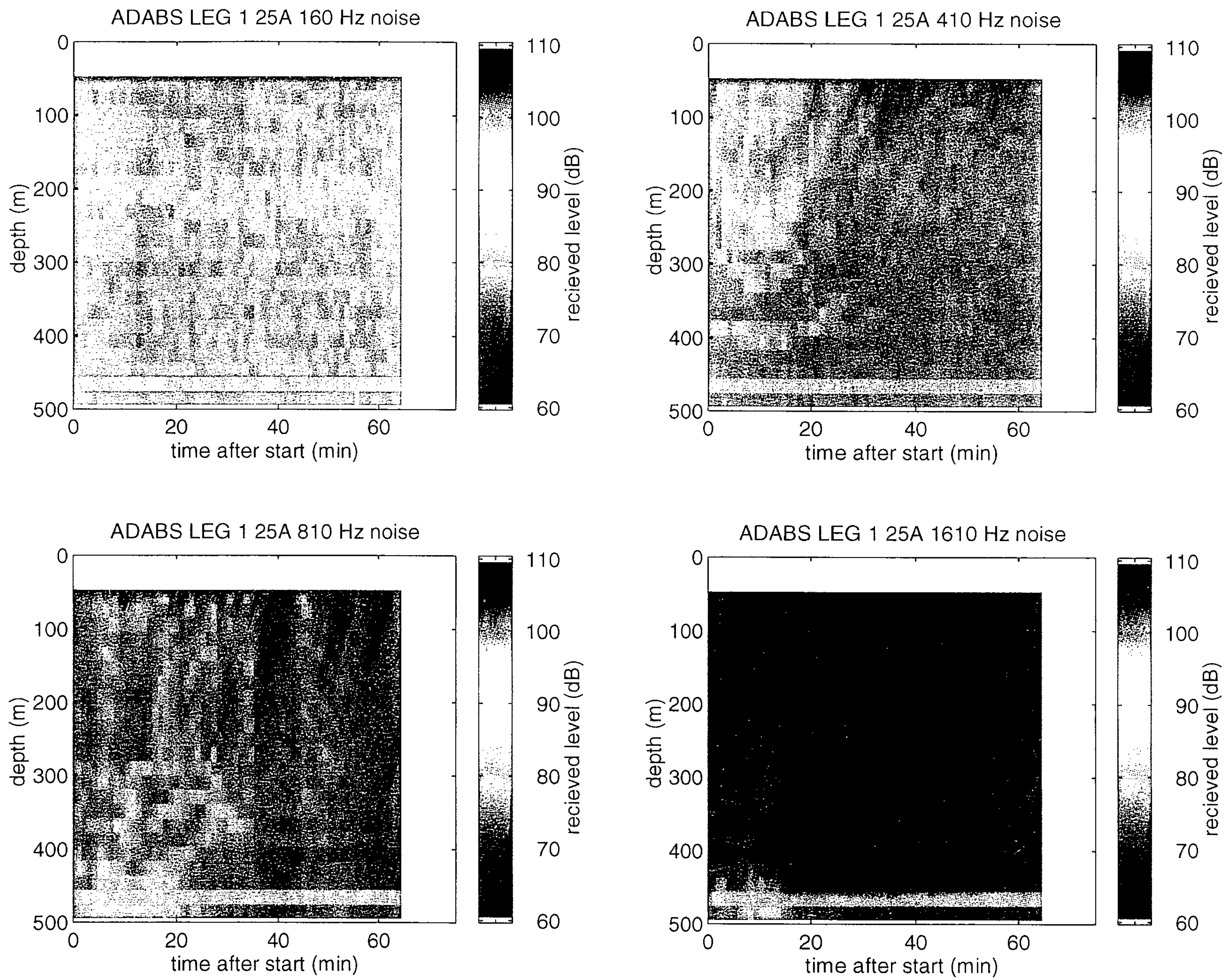

ADABS LEG 1 20A 410 Hz noise
depth (m)
time after start (min)
recieved level (dB)

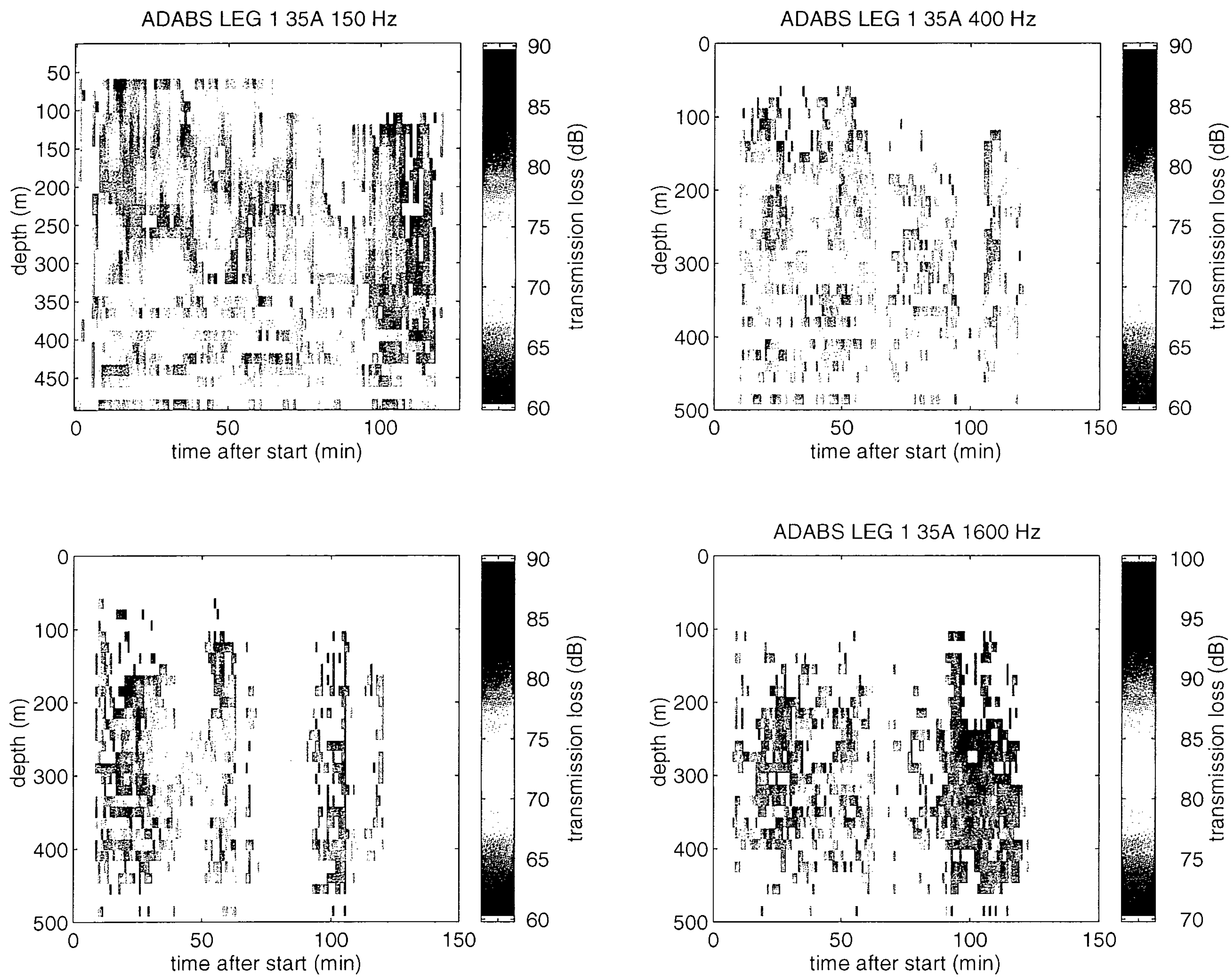

ADABS LEG 1 20A 810 Hz noise
depth (m)
time after start (min)
recieved level (dB)

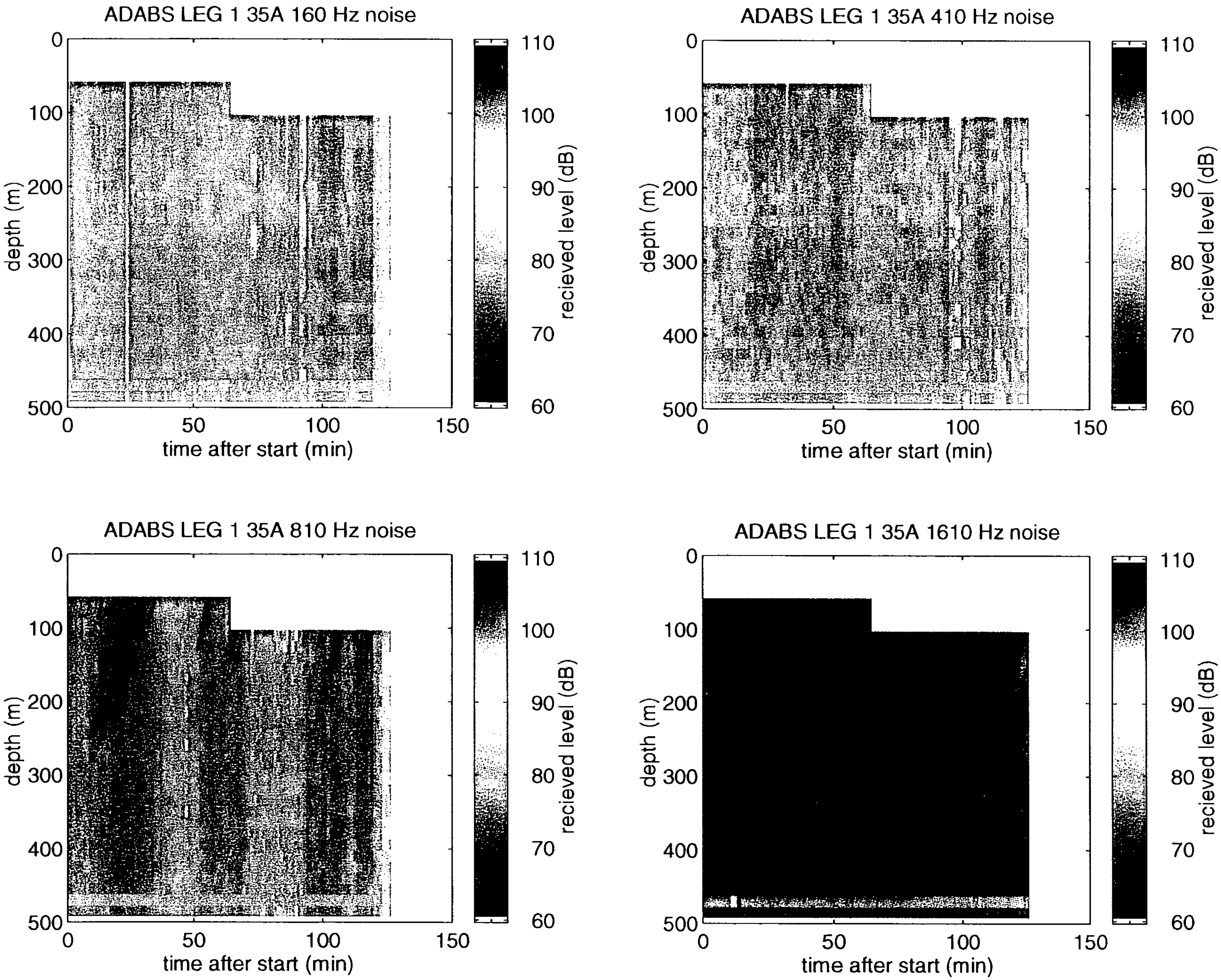

ADABS LEG 1 20A 1610 Hz noise
depth (m)
time after start (min)
recieved level (dB)

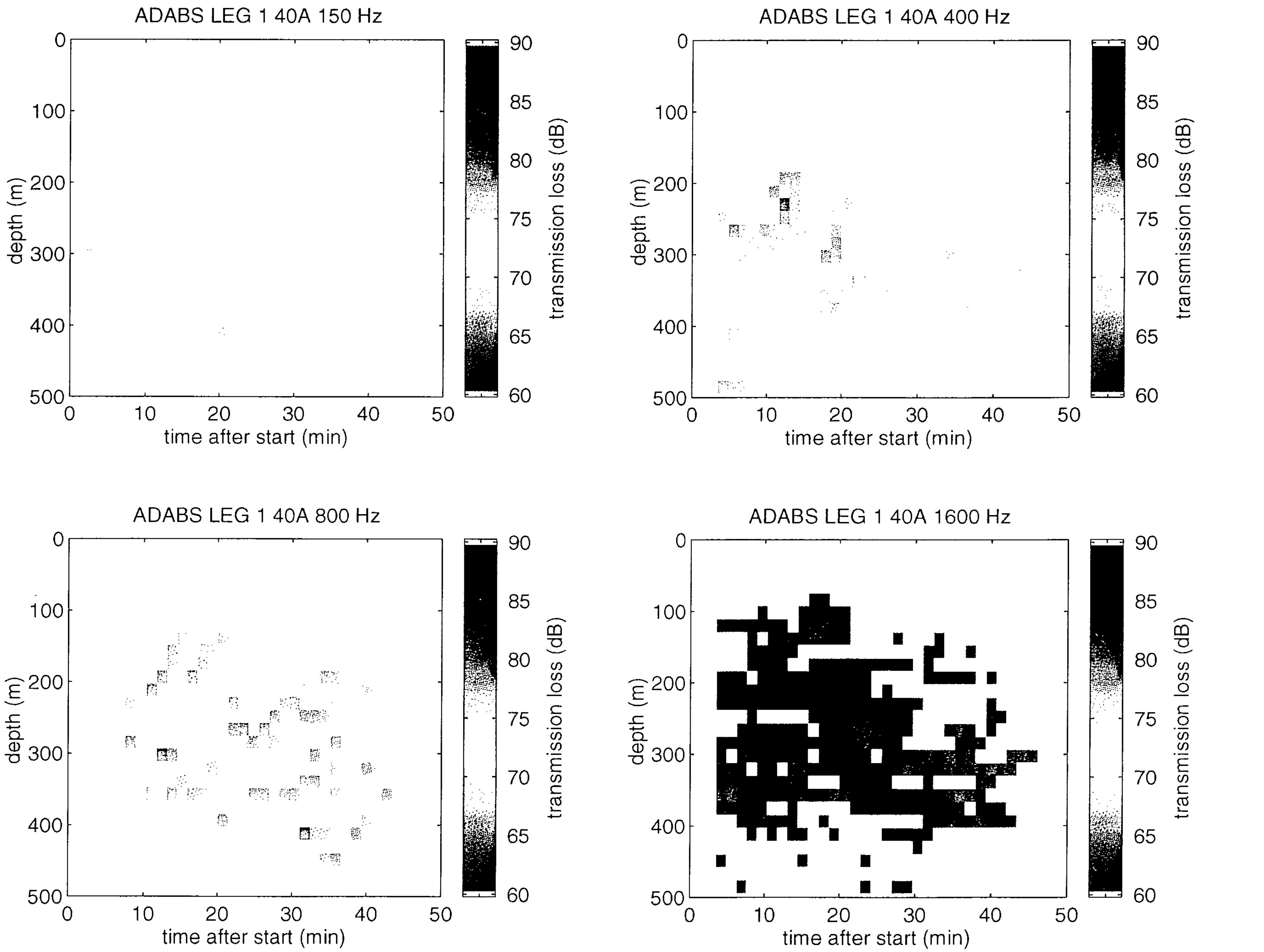


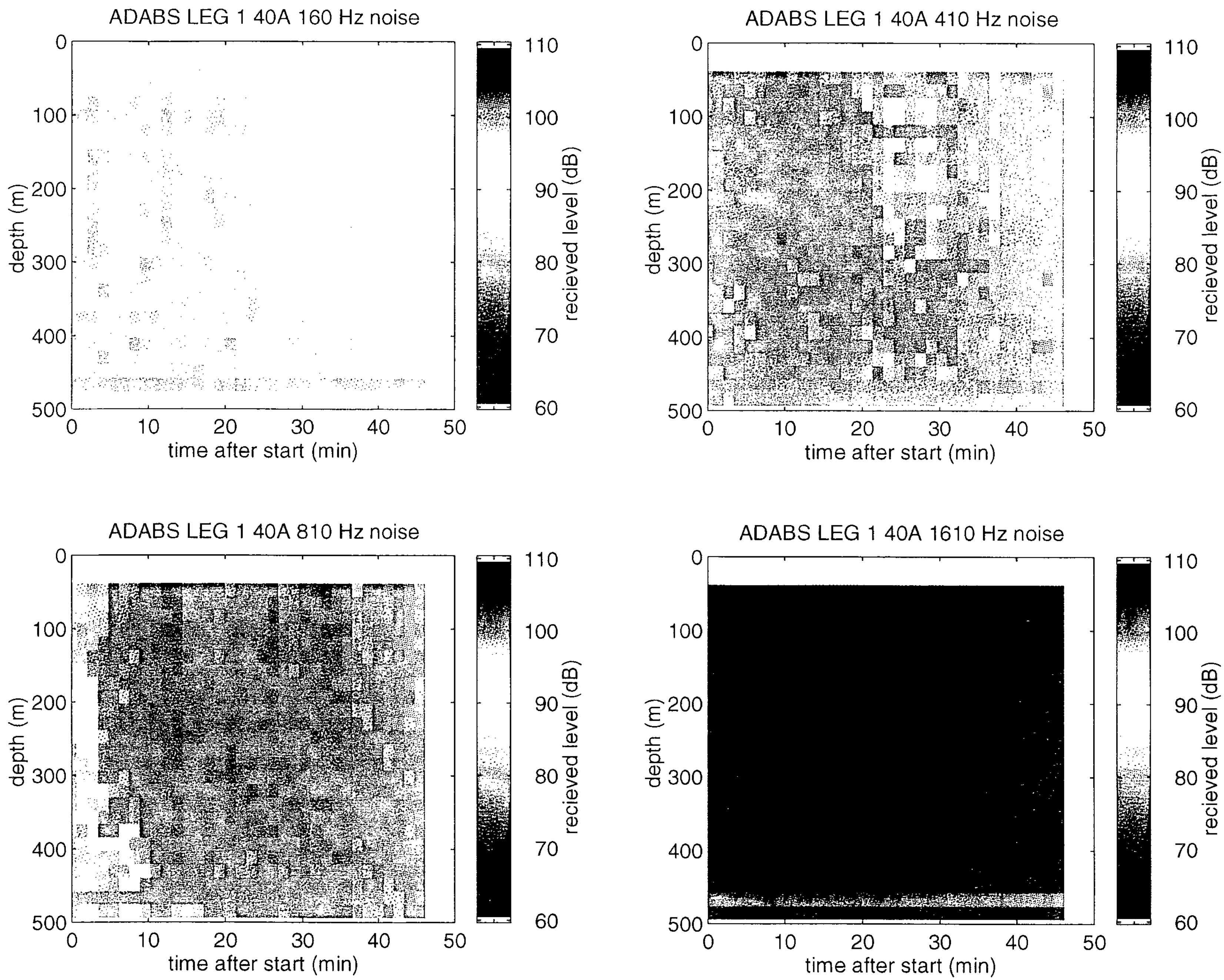
ADABS LEG 1 25A 150 Hz
ADABS LEG 1 25A 400 Hz
ADABS LEG 1 25A 800 Hz
ADABS LEG 1 25A 1600 Hz
depth (m)
time after start (min)
transmission loss (dB)
0
100
200
300
400
500
20
40
60
90
85
80
75
70
65
60

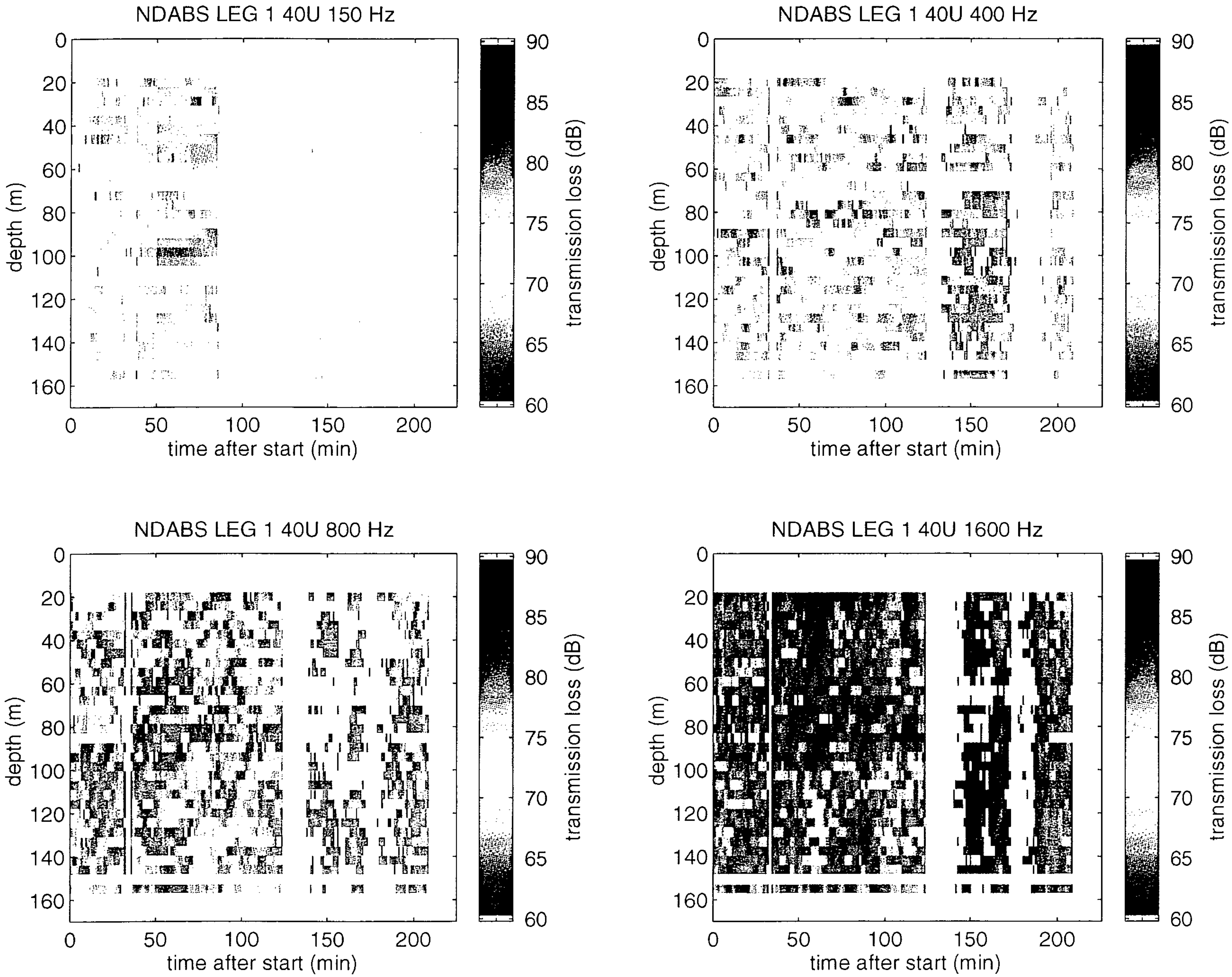

ADABS LEG 1 25A 160 Hz noise
ADABS LEG 1 25A 410 Hz noise
ADABS LEG 1 25A 810 Hz noise
ADABS LEG 1 25A 1610 Hz noise
depth (m)
time after start (min)
recieved level (dB)
0
100
200
300
400
500
20
40
60
70
80
90
110

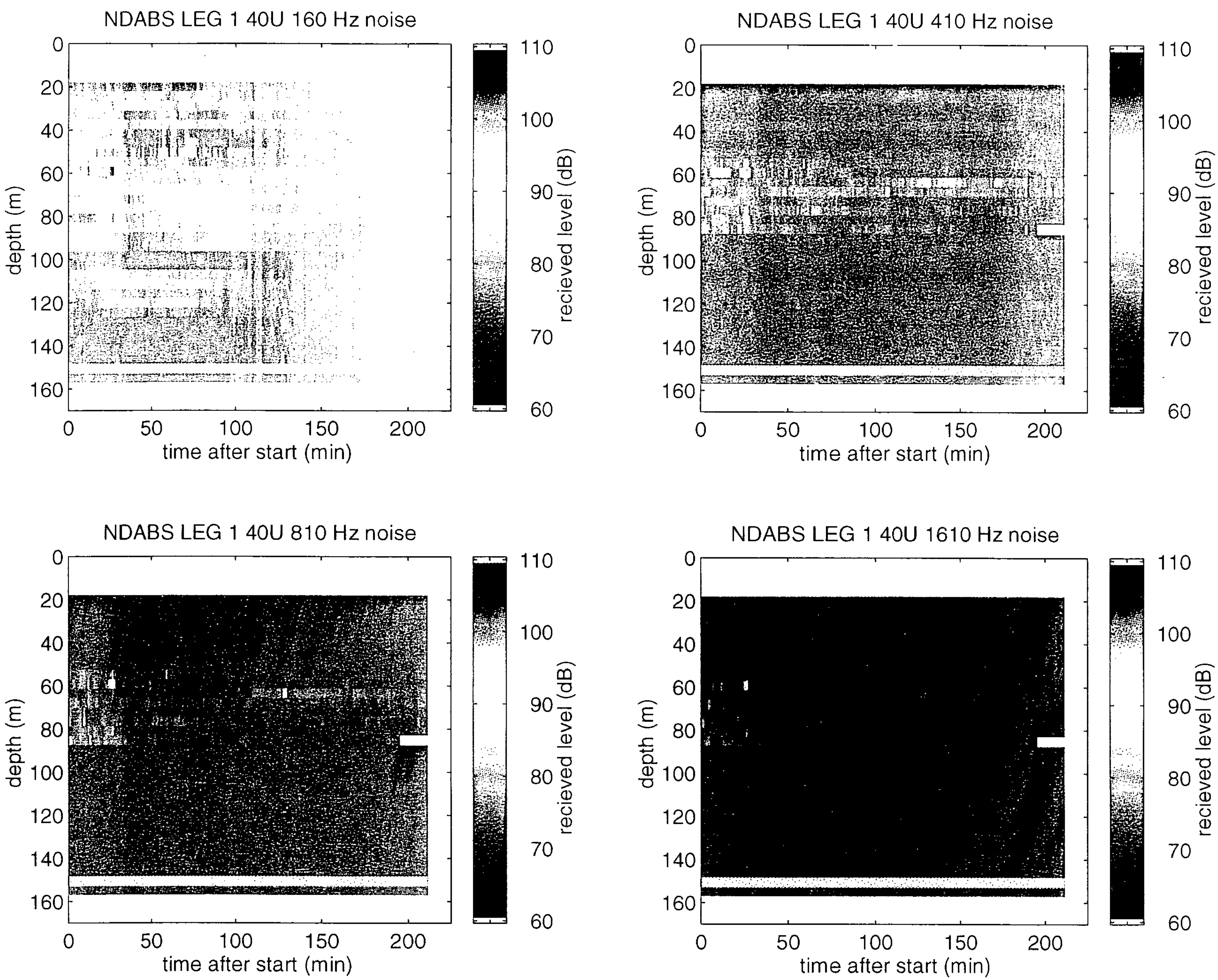

ADABS LEG 1 35A 150 Hz
depth (m)
time after start (min)
transmission loss (dB)
ADABS LEG 1 35A 400 Hz
depth (m)
time after start (min)
transmission loss (dB)
depth (m)
time after start (min)
transmission loss (dB)
ADABS LEG 1 35A 1600 Hz
depth (m)
time after start (min)
transmission loss (dB)

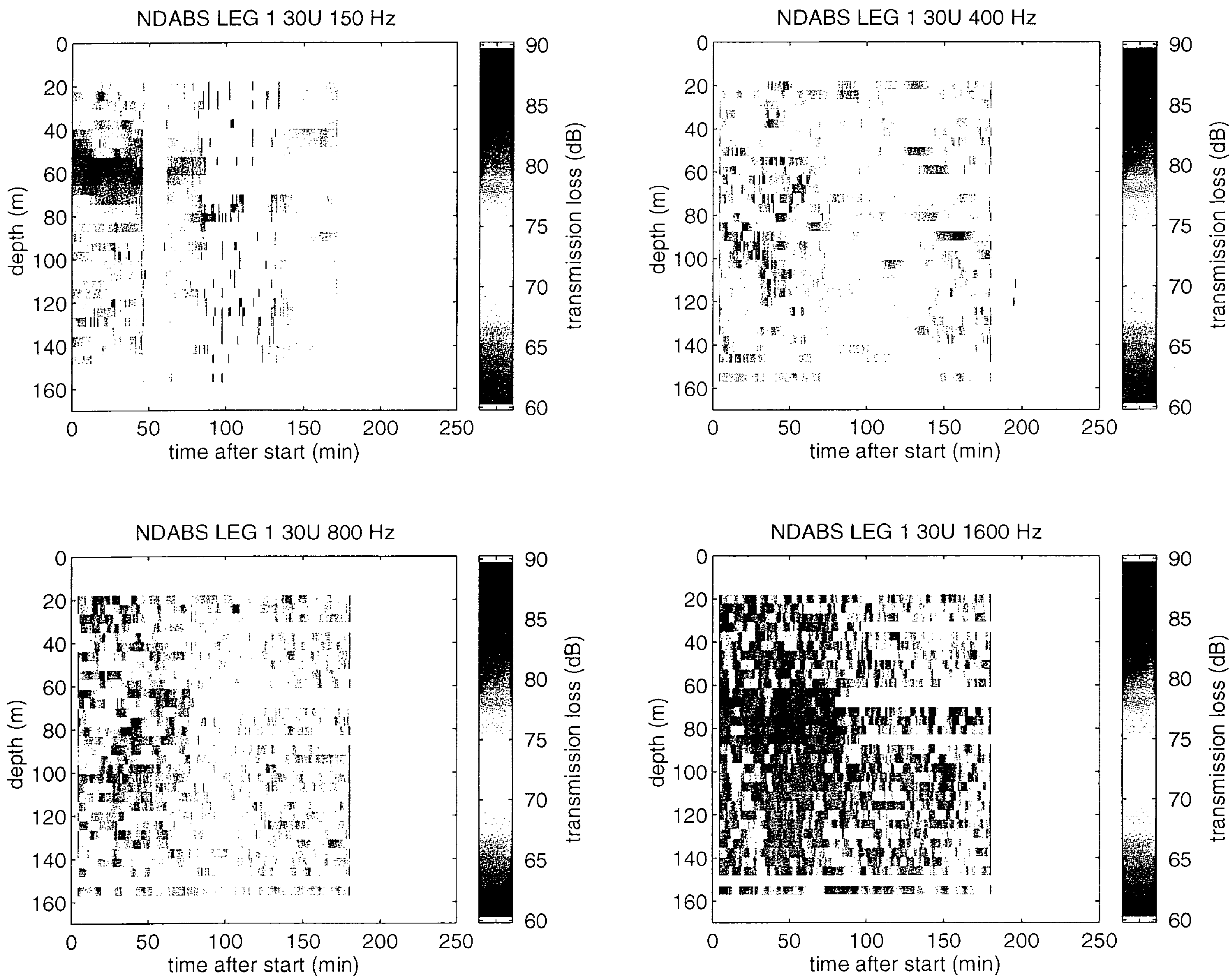

ADABS LEG 1 35A 160 Hz noise
ADABS LEG 1 35A 410 Hz noise
ADABS LEG 1 35A 810 Hz noise
ADABS LEG 1 35A 1610 Hz noise
depth (m)
time after start (min)
recieved level (dB)
0
100
200
300
400
500
50
150
60
70
80
90
110


ADABS LEG 1 40A 150 Hz
ADABS LEG 1 40A 400 Hz
ADABS LEG 1 40A 800 Hz
ADABS LEG 1 40A 1600 Hz
depth (m)
time after start (min)
transmission loss (dB)

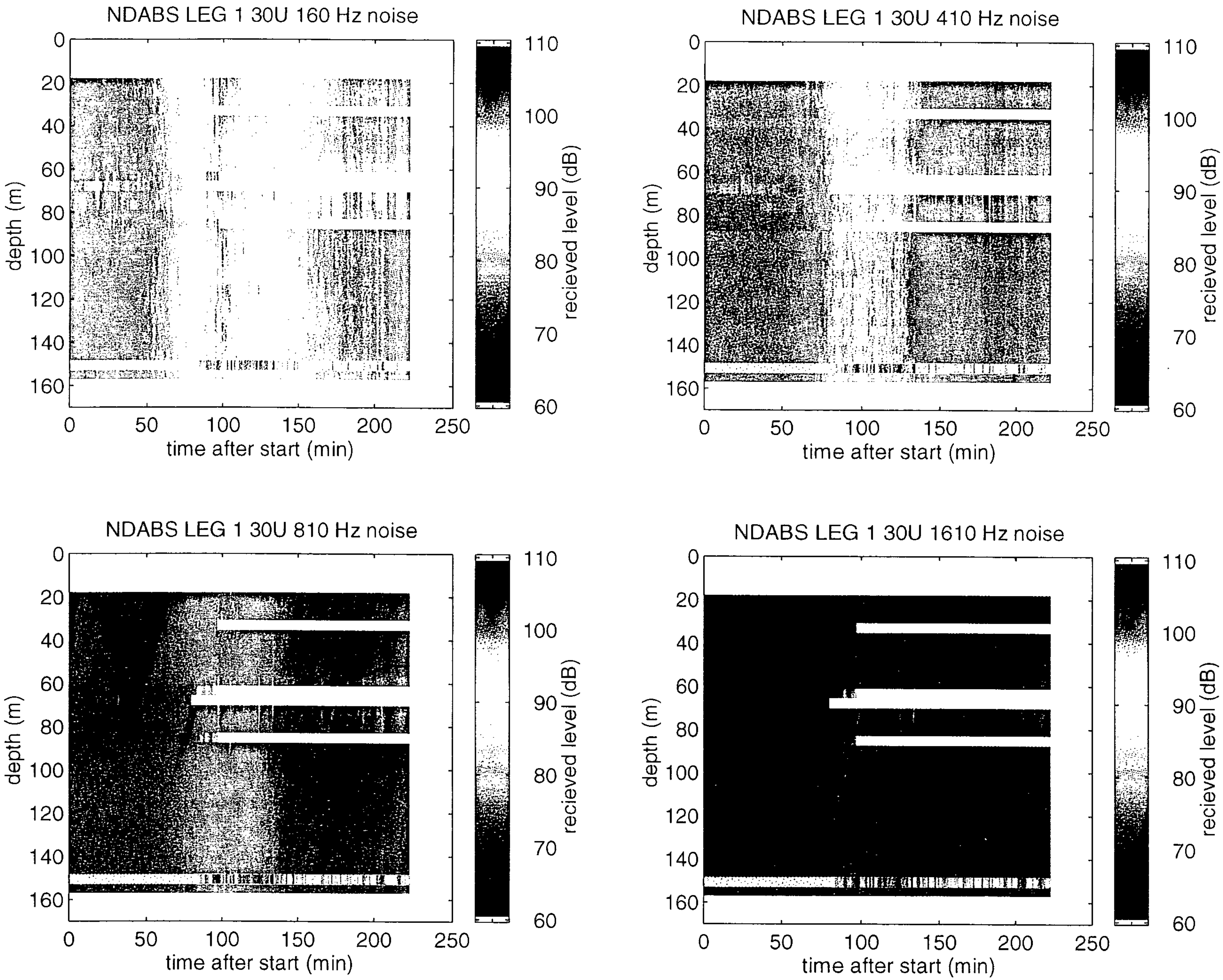

ADABS LEG 1 40A 160 Hz noise
ADABS LEG 1 40A 410 Hz noise
ADABS LEG 1 40A 810 Hz noise
ADABS LEG 1 40A 1610 Hz noise
depth (m)
time after start (min)
recieved level (dB)
0
100
200
300
400
500
10
20
30
40
50
60
70
80
90
110

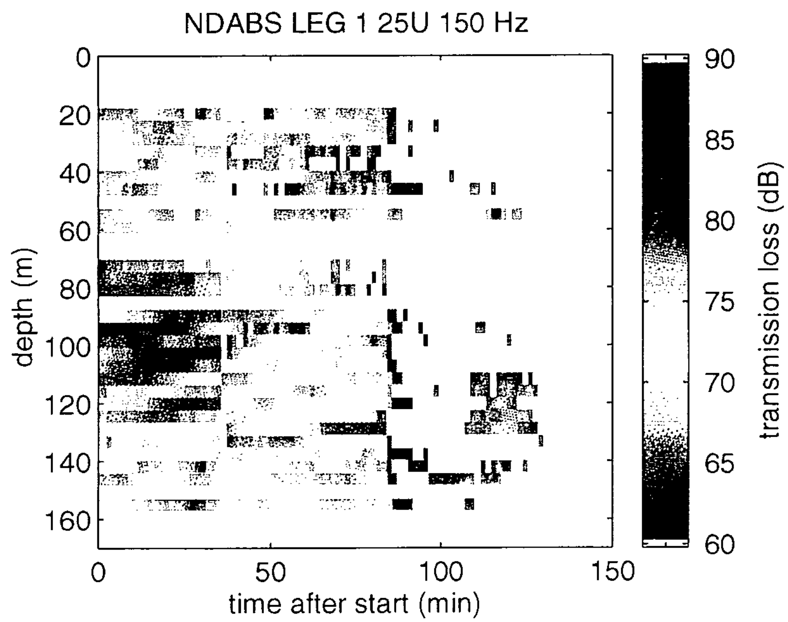

NDABS LEG 1 40U 150 Hz
NDABS LEG 1 40U 400 Hz
NDABS LEG 1 40U 800 Hz
NDABS LEG 1 40U 1600 Hz
depth (m)
time after start (min)
transmission loss (dB)
0
20
40
60
80
100
120
140
160
50
150
200
60
65
70
75
80
85
90

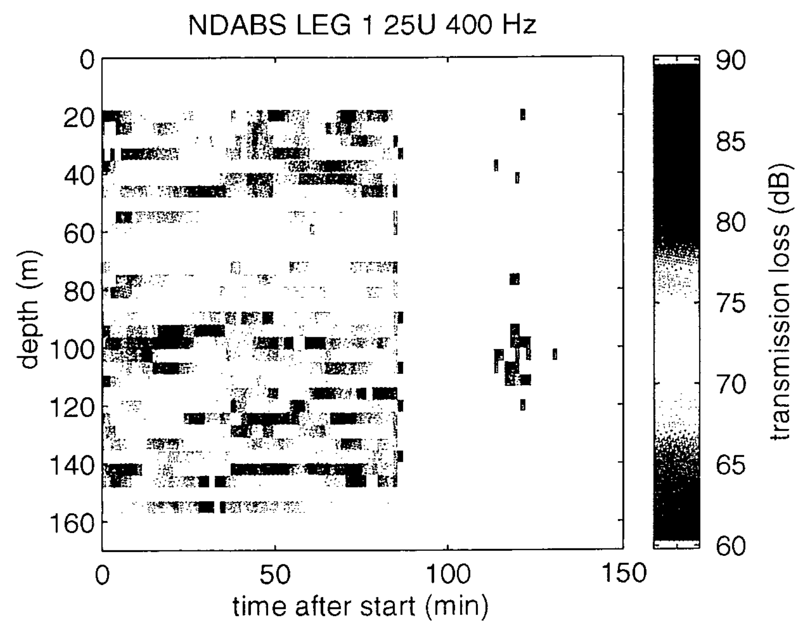

NDABS LEG 1 40U 160 Hz noise
NDABS LEG 1 40U 410 Hz noise
NDABS LEG 1 40U 810 Hz noise
NDABS LEG 1 40U 1610 Hz noise
depth (m)
time after start (min)
recieved level (dB)
0
20
40
60
80
100
120
140
160
0
50
100
150
200
60
70
80
90
100
110

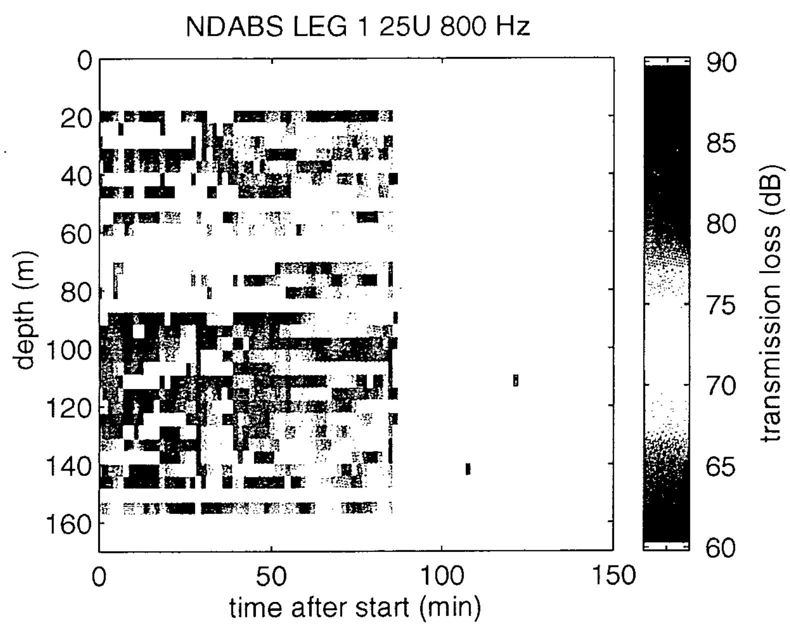


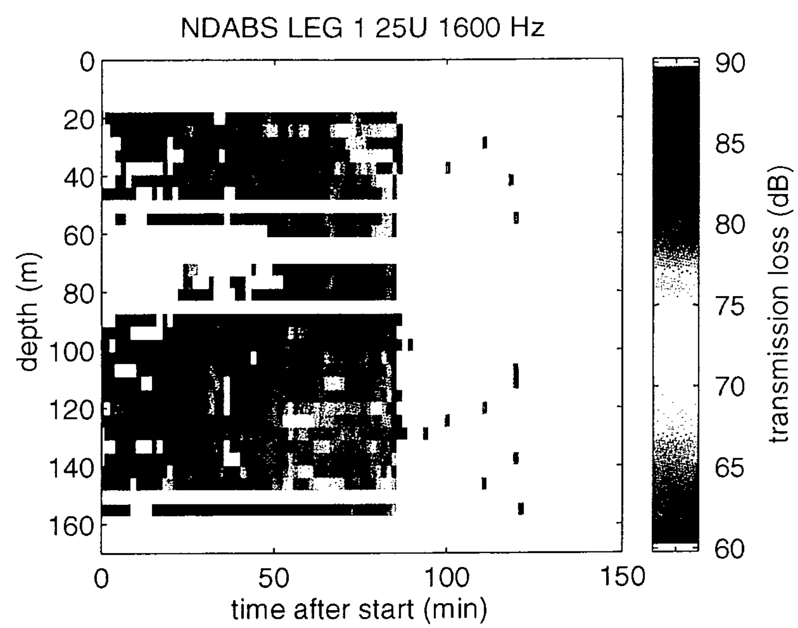
NDABS LEG 1 30U 150 Hz
NDABS LEG 1 30U 400 Hz
NDABS LEG 1 30U 800 Hz
NDABS LEG 1 30U 1600 Hz
depth (m)
time after start (min)
transmission loss (dB)

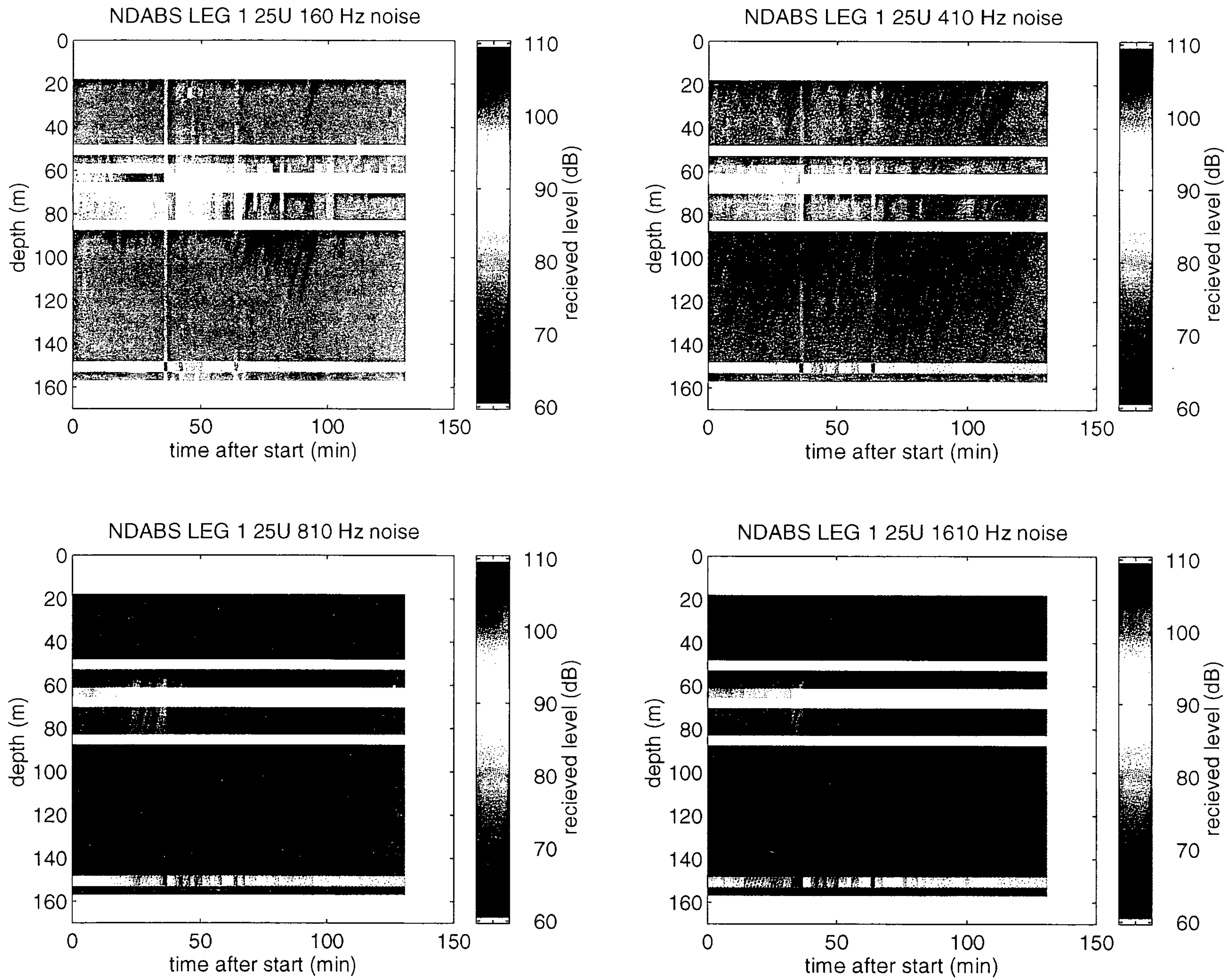

NDABS LEG 1 30U 160 Hz noise
NDABS LEG 1 30U 410 Hz noise
NDABS LEG 1 30U 810 Hz noise
NDABS LEG 1 30U 1610 Hz noise
depth (m)
time after start (min)
recieved level (dB)

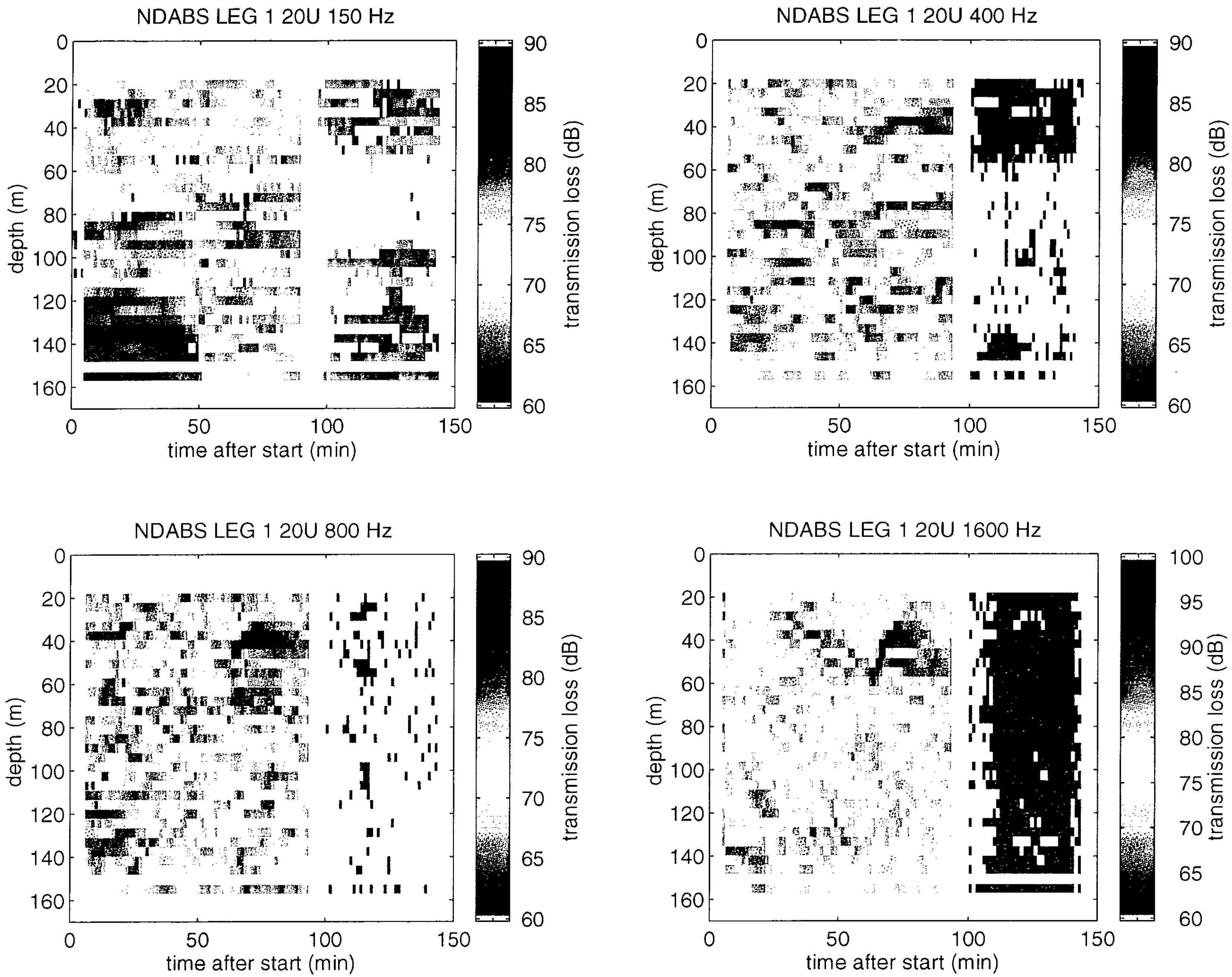

NDABS LEG 1 25U 150 Hz
depth (m)
time after start (min)
transmission loss (dB)

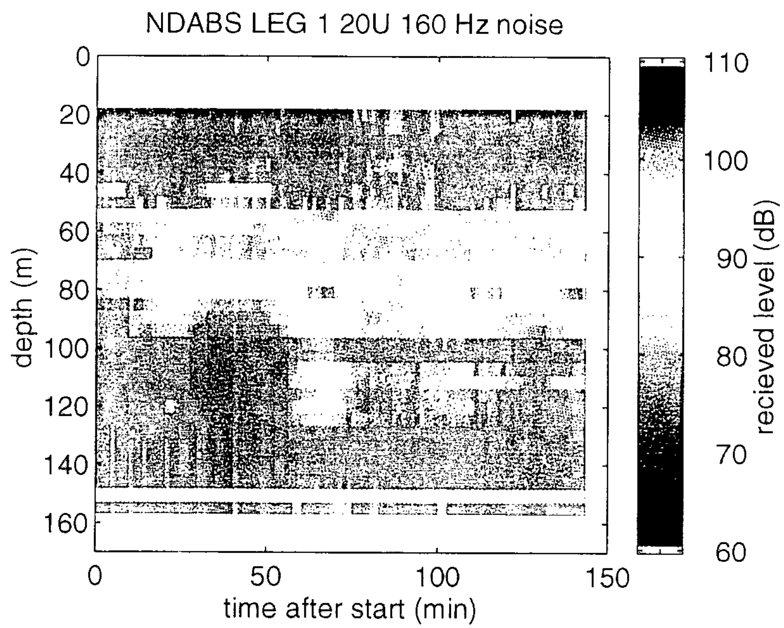

NDABS LEG 1 25U 400 Hz
depth (m)
time after start (min)
transmission loss (dB)

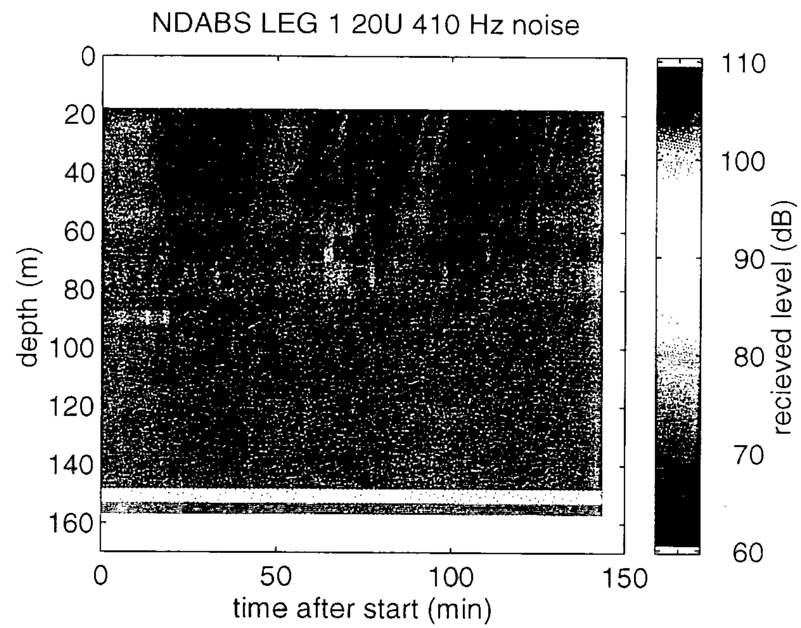

NDABS LEG 1 25U 800 Hz
depth (m)
time after start (min)
transmission loss (dB)

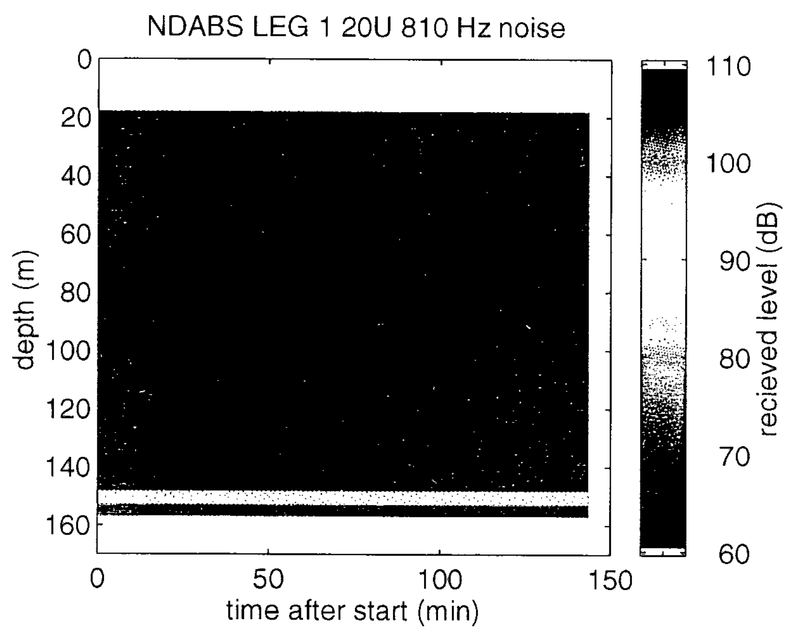

NDABS LEG 1 25U 1600 Hz
depth (m)
time after start (min)
transmission loss (dB)

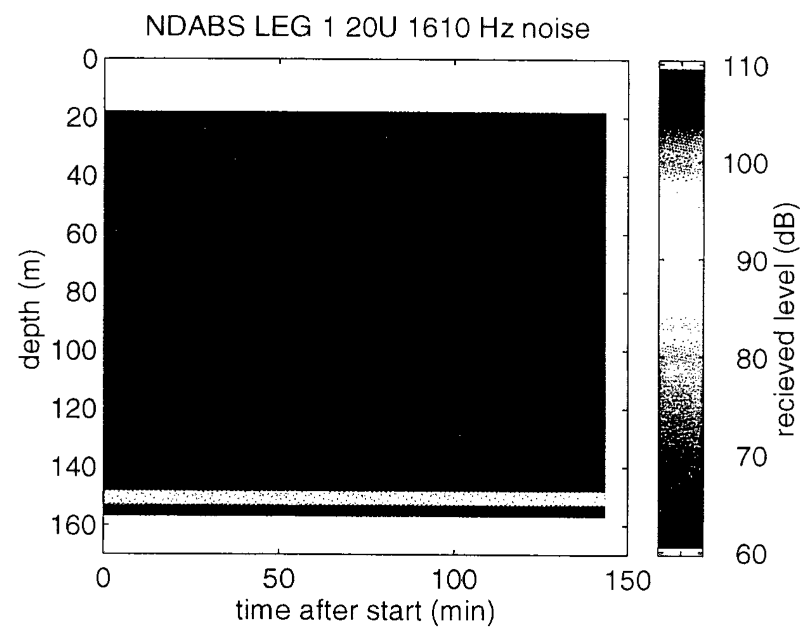

NDABS LEG 1 25U 160 Hz noise
NDABS LEG 1 25U 410 Hz noise
NDABS LEG 1 25U 810 Hz noise
NDABS LEG 1 25U 1610 Hz noise
depth (m)
time after start (min)
recieved level (dB)
0
20
40
60
80
100
120
140
160
50
150
110
90
70

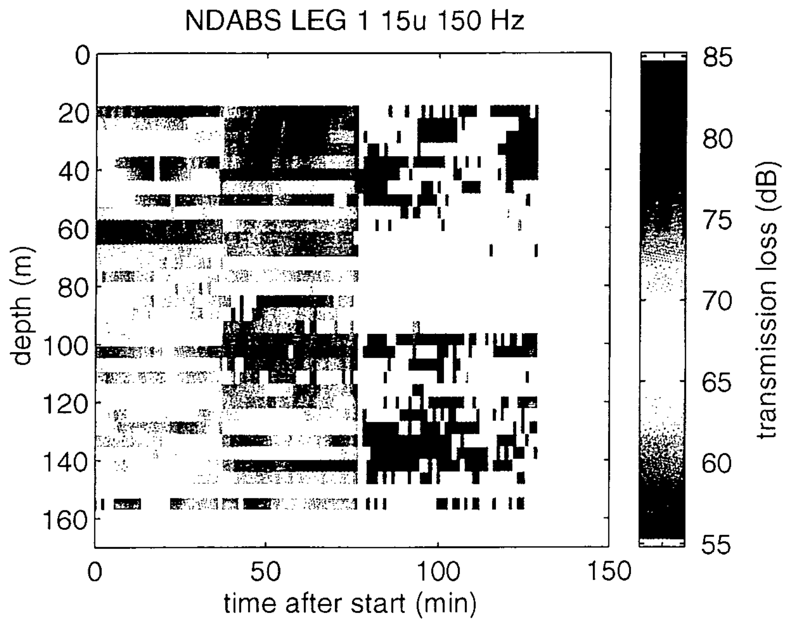

NDABS LEG 1 20U 150 Hz
depth (m)
time after start (min)
transmission loss (dB)
NDABS LEG 1 20U 400 Hz
depth (m)
time after start (min)
transmission loss (dB)
NDABS LEG 1 20U 800 Hz
depth (m)
time after start (min)
transmission loss (dB)
NDABS LEG 1 20U 1600 Hz
depth (m)
time after start (min)
transmission loss (dB)

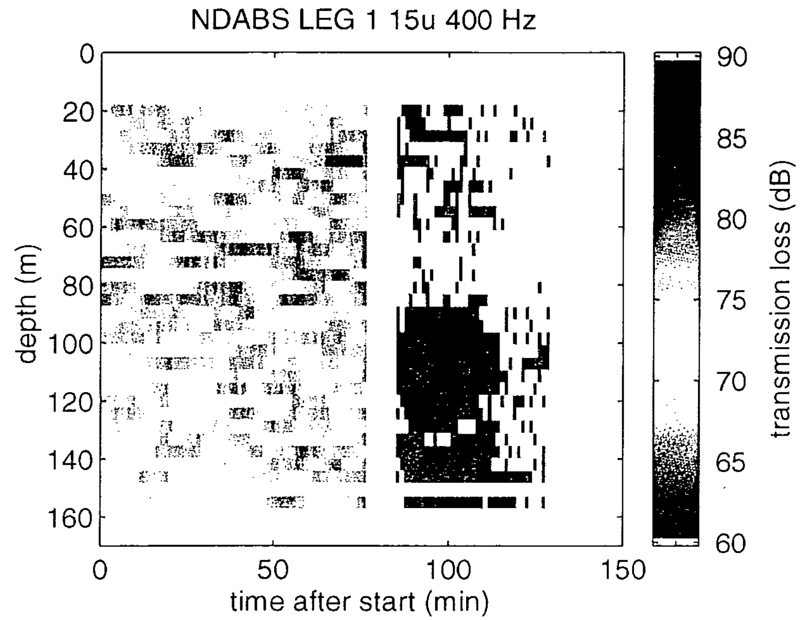

NDABS LEG 1 20U 160 Hz noise
depth (m)
time after start (min)
recieved level (dB)

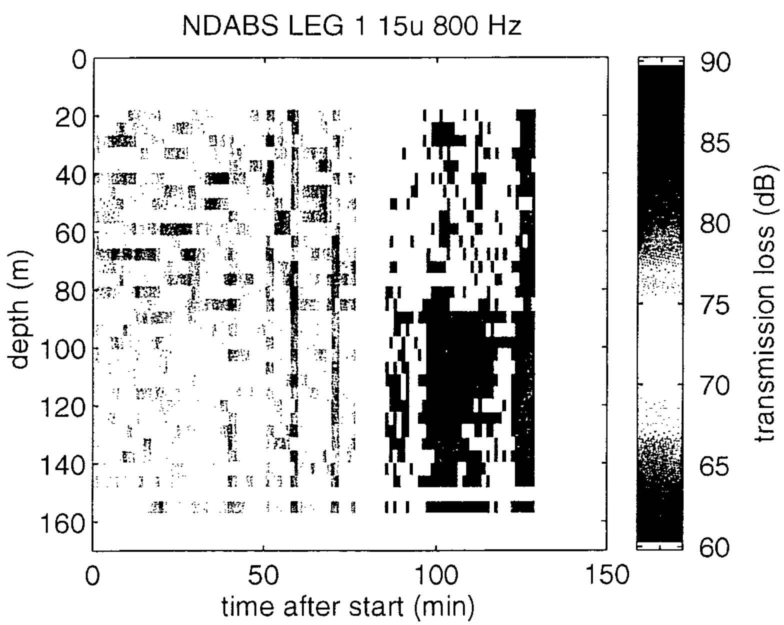

NDABS LEG 1 20U 410 Hz noise
depth (m)
time after start (min)
recieved level (dB)

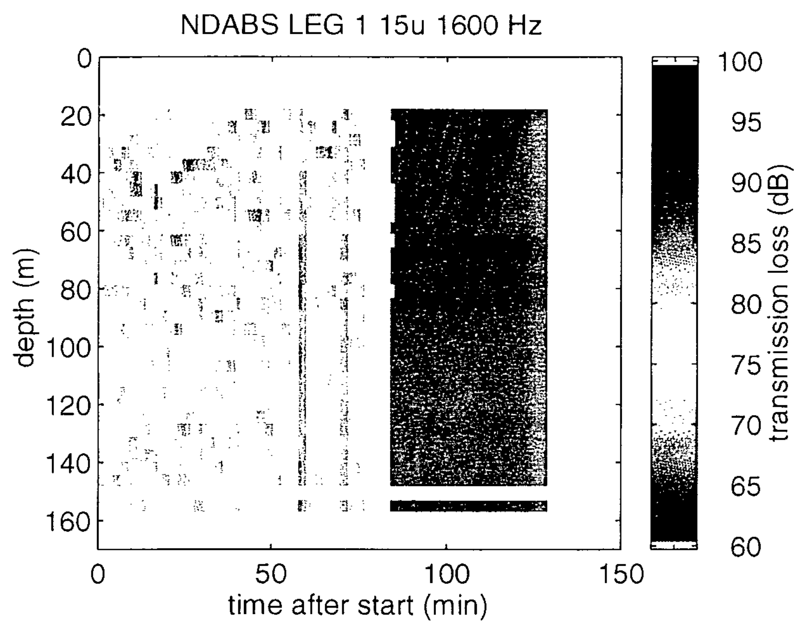

NDABS LEG 1 20U 810 Hz noise
depth (m)
time after start (min)
recieved level (dB)

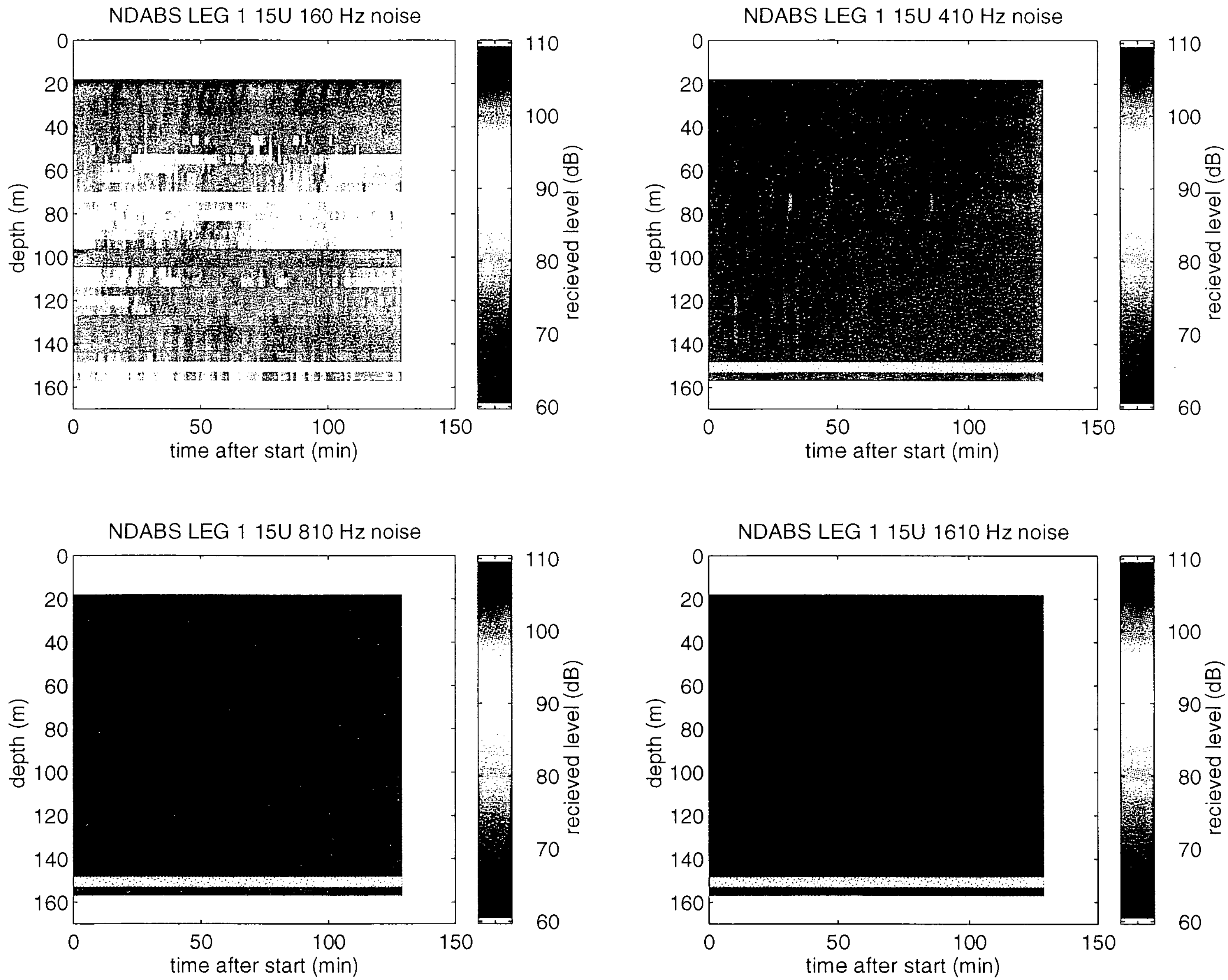

NDABS LEG 1 20U 1610 Hz noise
depth (m)
time after start (min)
recieved level (dB)

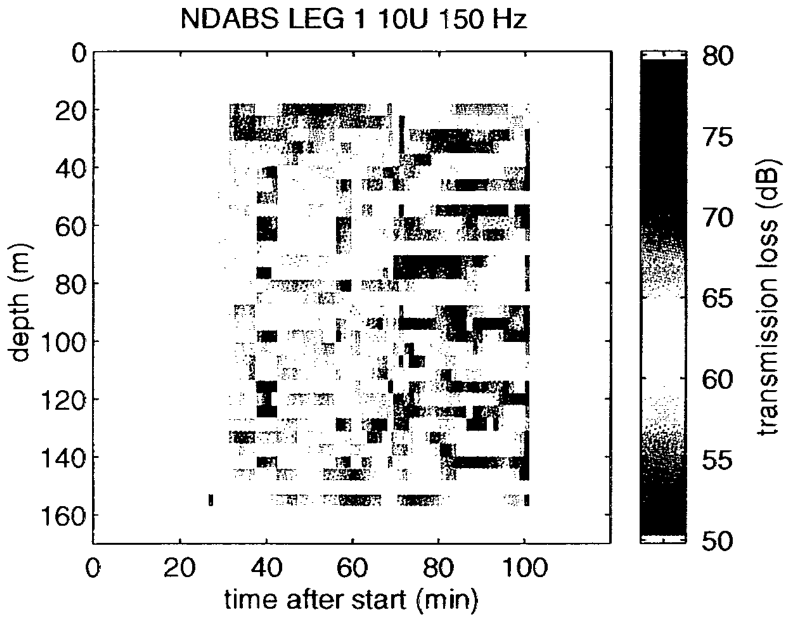

NDABS LEG 1 15u 150 Hz
depth (m)
0
20
40
60
80
100
120
140
160
0
50
100
150
time after start (min)
85
80
75
70
65
60
55
transmission loss (dB)

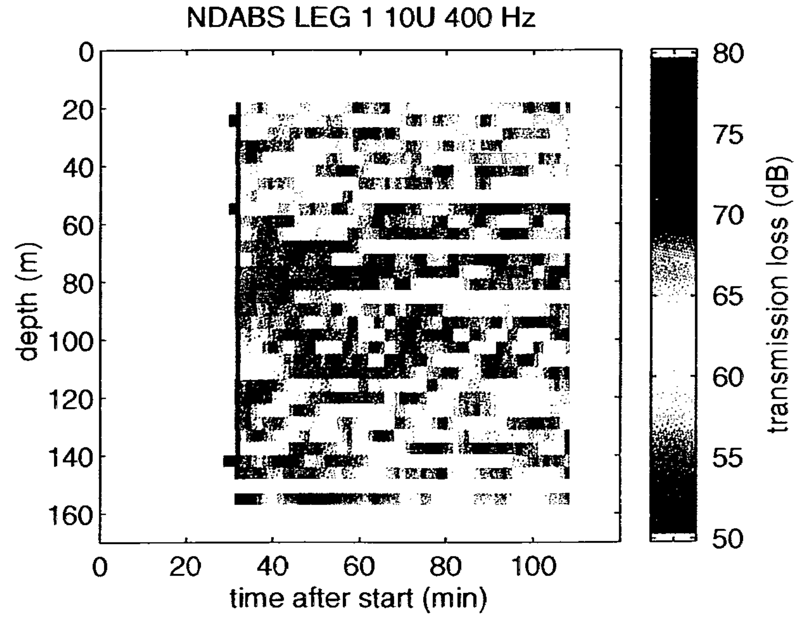

NDABS LEG 1 15u 400 Hz
depth (m)
0
20
40
60
80
100
120
140
160
0
50
100
150
time after start (min)
90
85
80
75
70
65
60
transmission loss (dB)

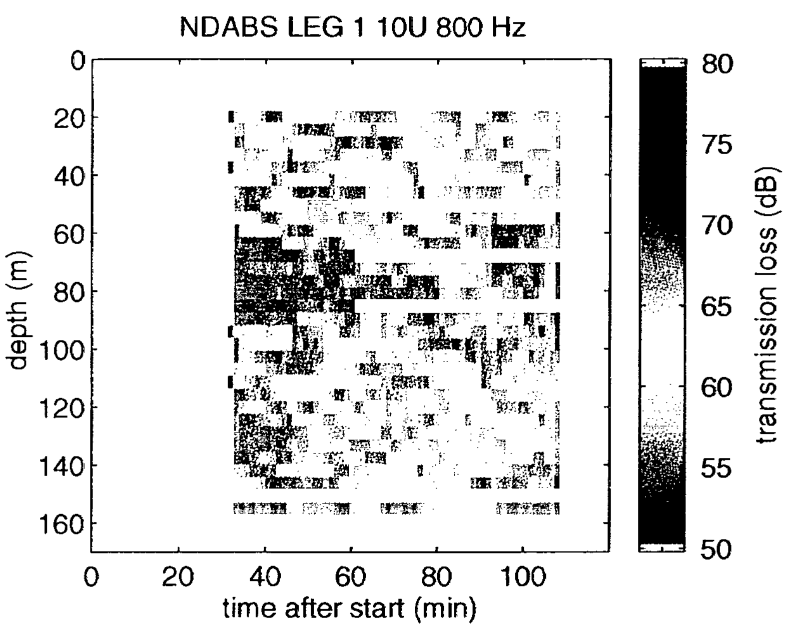

NDABS LEG 1 15u 800 Hz
depth (m)
0
20
40
60
80
100
120
140
160
0
50
100
150
time after start (min)
90
85
80
75
70
65
60
transmission loss (dB)

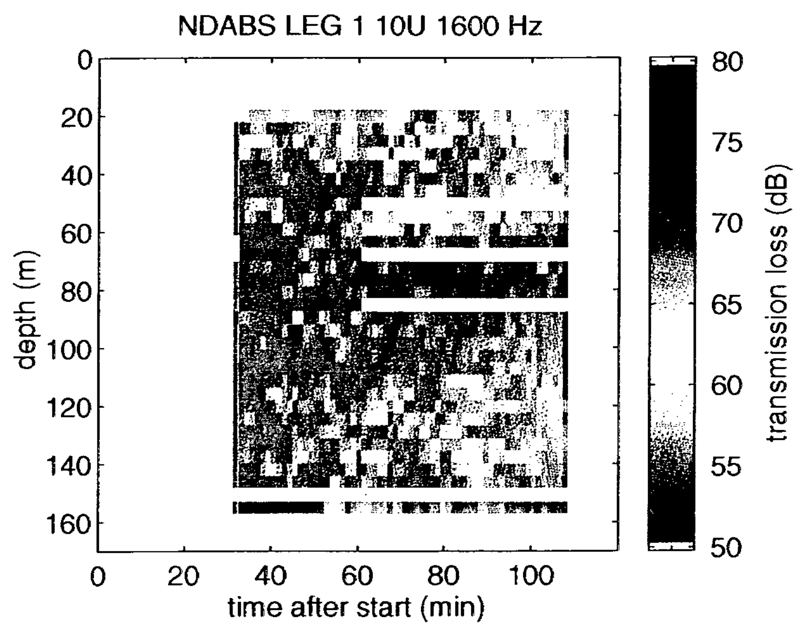

NDABS LEG 1 15u 1600 Hz
depth (m)
0
20
40
60
80
100
120
140
160
0
50
100
150
time after start (min)
100
95
90
85
80
75
70
65
60
transmission loss (dB)

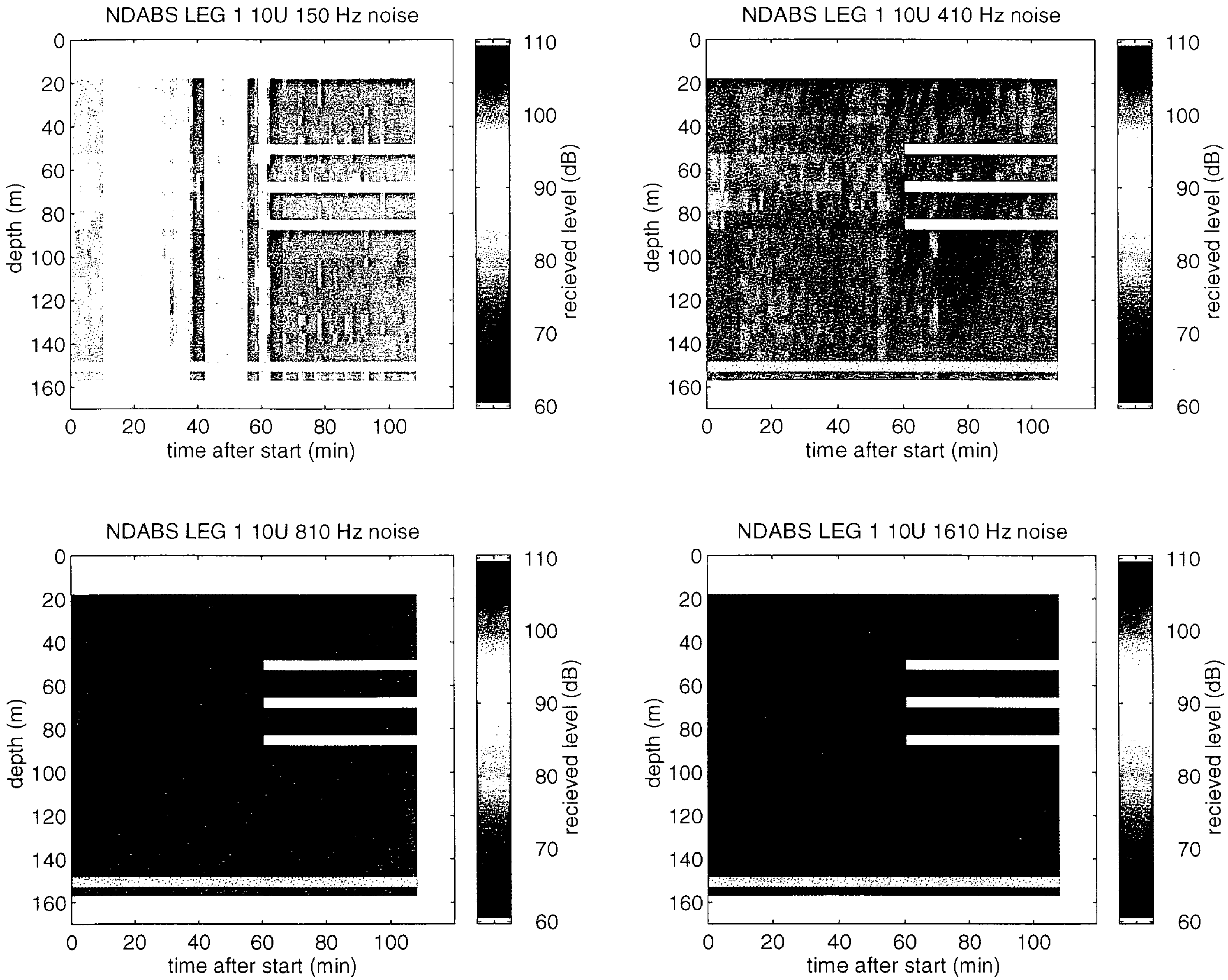

NDABS LEG 1 15U 160 Hz noise
NDABS LEG 1 15U 410 Hz noise
NDABS LEG 1 15U 810 Hz noise
NDABS LEG 1 15U 1610 Hz noise
depth (m)
time after start (min)
recieved level (dB)
0
20
40
60
80
100
120
140
160
0
50
100
150
60
70
80
90
100
110


NDABS LEG 1 10U 150 Hz
depth (m)
time after start (min)
transmission loss (dB)
0 20 40 60 80 100 120 140 160
0 20 40 60 80 100
80 75 70 65 60 55 50

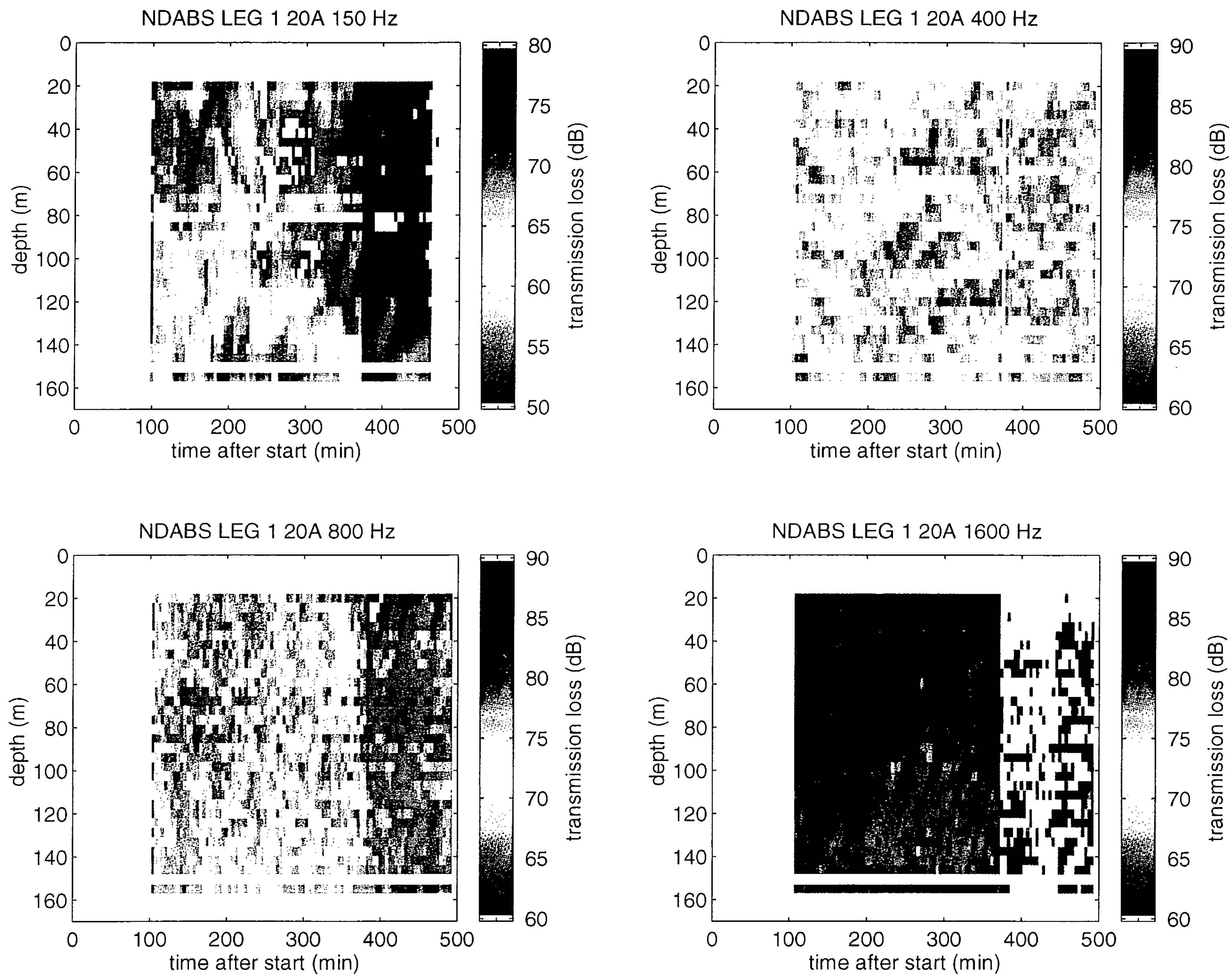

NDABS LEG 1 10U 400 Hz
depth (m)
time after start (min)
transmission loss (dB)
0 20 40 60 80 100 120 140 160
0 20 40 60 80 100
80 75 70 65 60 55 50

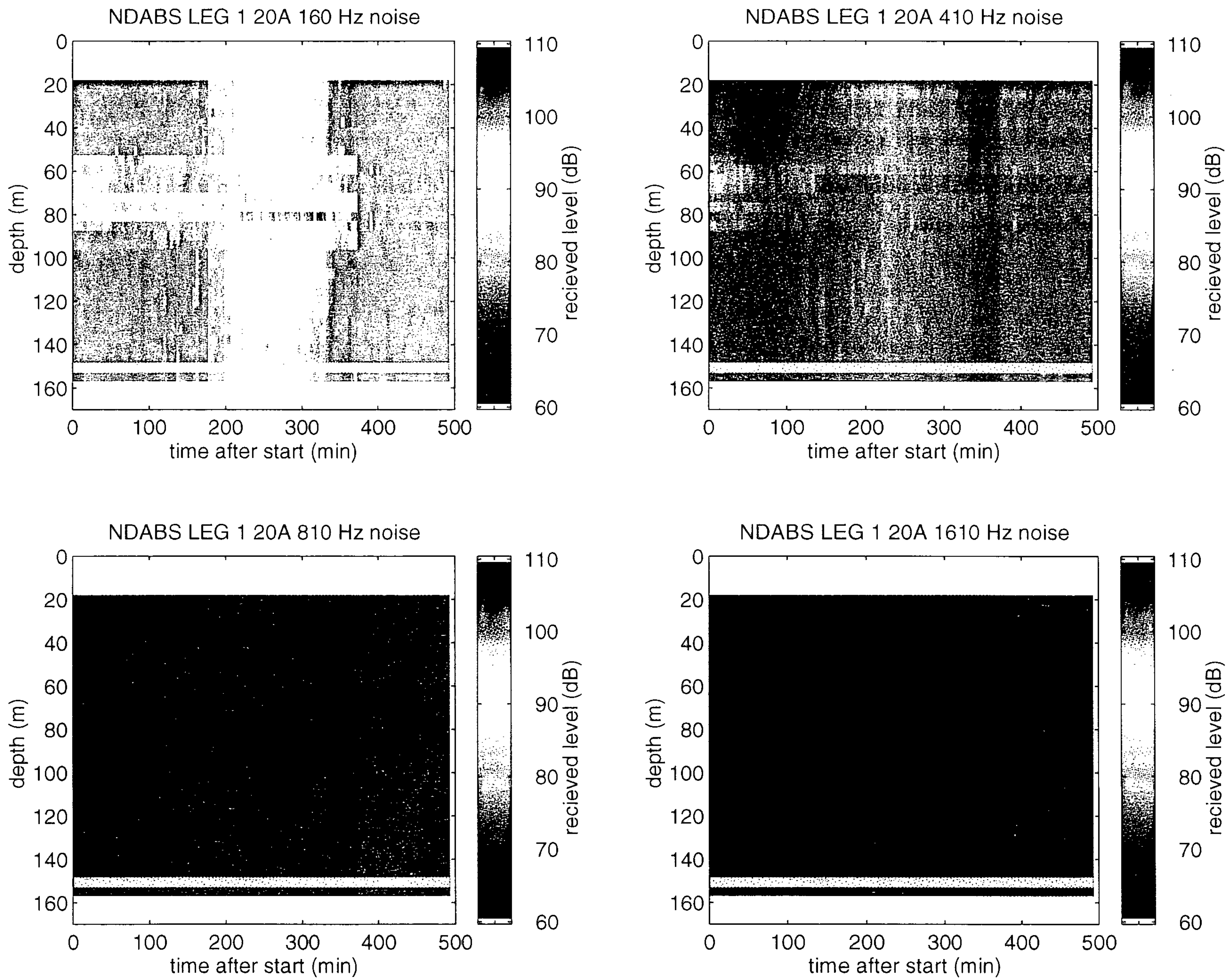

NDABS LEG 1 10U 800 Hz
depth (m)
time after start (min)
transmission loss (dB)
0 20 40 60 80 100 120 140 160
0 20 40 60 80 100
80 75 70 65 60 55 50

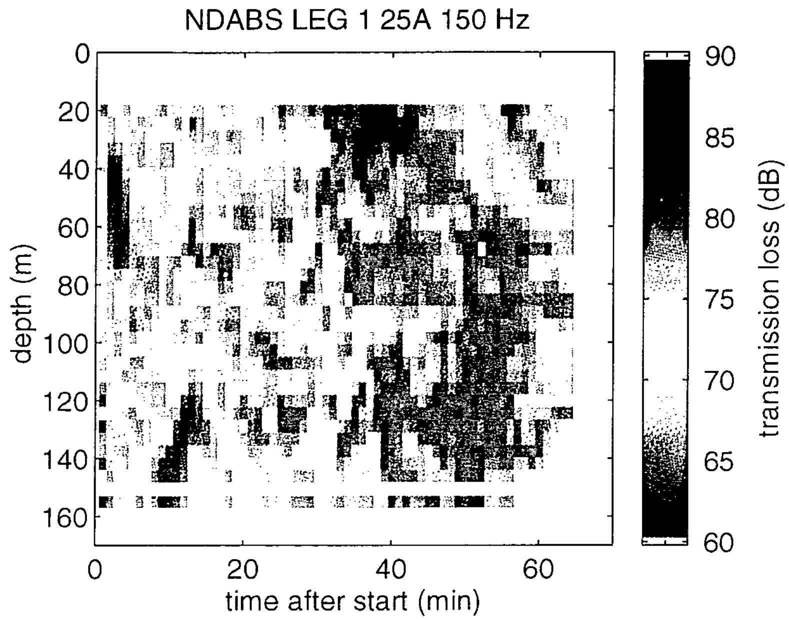

NDABS LEG 1 10U 1600 Hz
depth (m)
time after start (min)
transmission loss (dB)
0 20 40 60 80 100 120 140 160
0 20 40 60 80 100
80 75 70 65 60 55 50

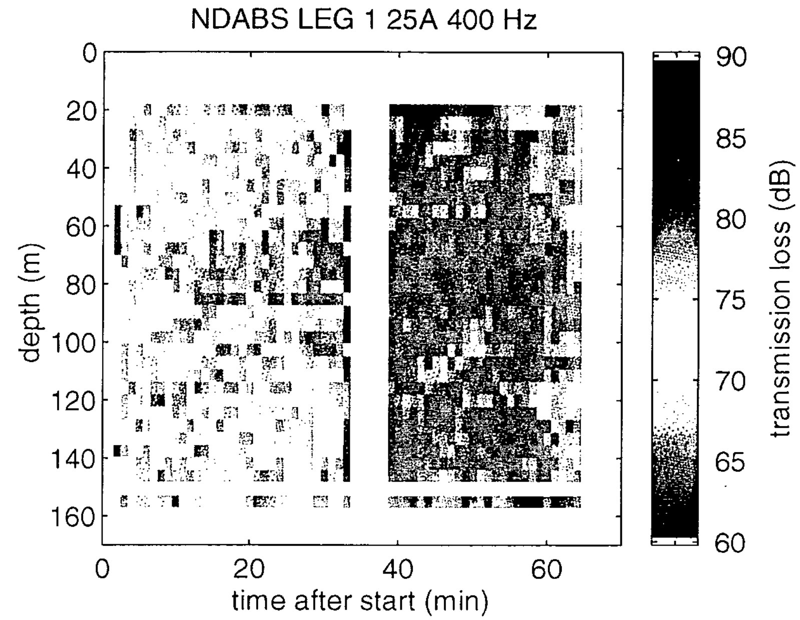


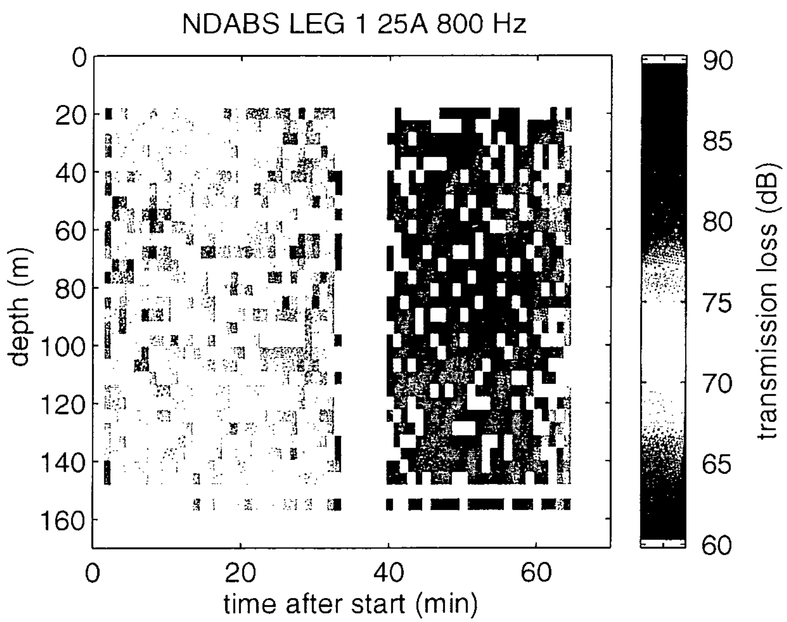
NDABS LEG 1 10U 150 Hz noise
NDABS LEG 1 10U 410 Hz noise
NDABS LEG 1 10U 810 Hz noise
NDABS LEG 1 10U 1610 Hz noise
depth (m)
time after start (min)
recieved level (dB)

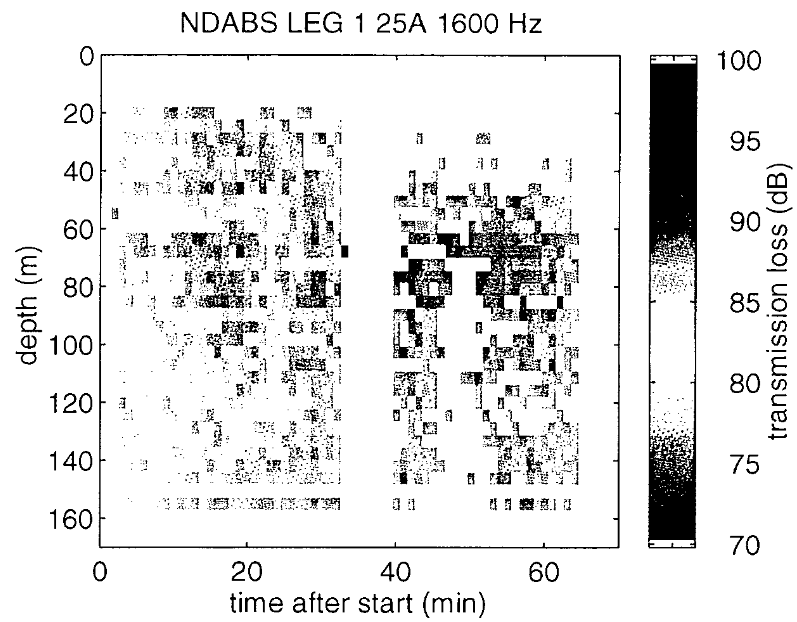

NDABS LEG 1 20A 150 Hz
NDABS LEG 1 20A 400 Hz
NDABS LEG 1 20A 800 Hz
NDABS LEG 1 20A 1600 Hz
depth (m)
time after start (min)
transmission loss (dB)

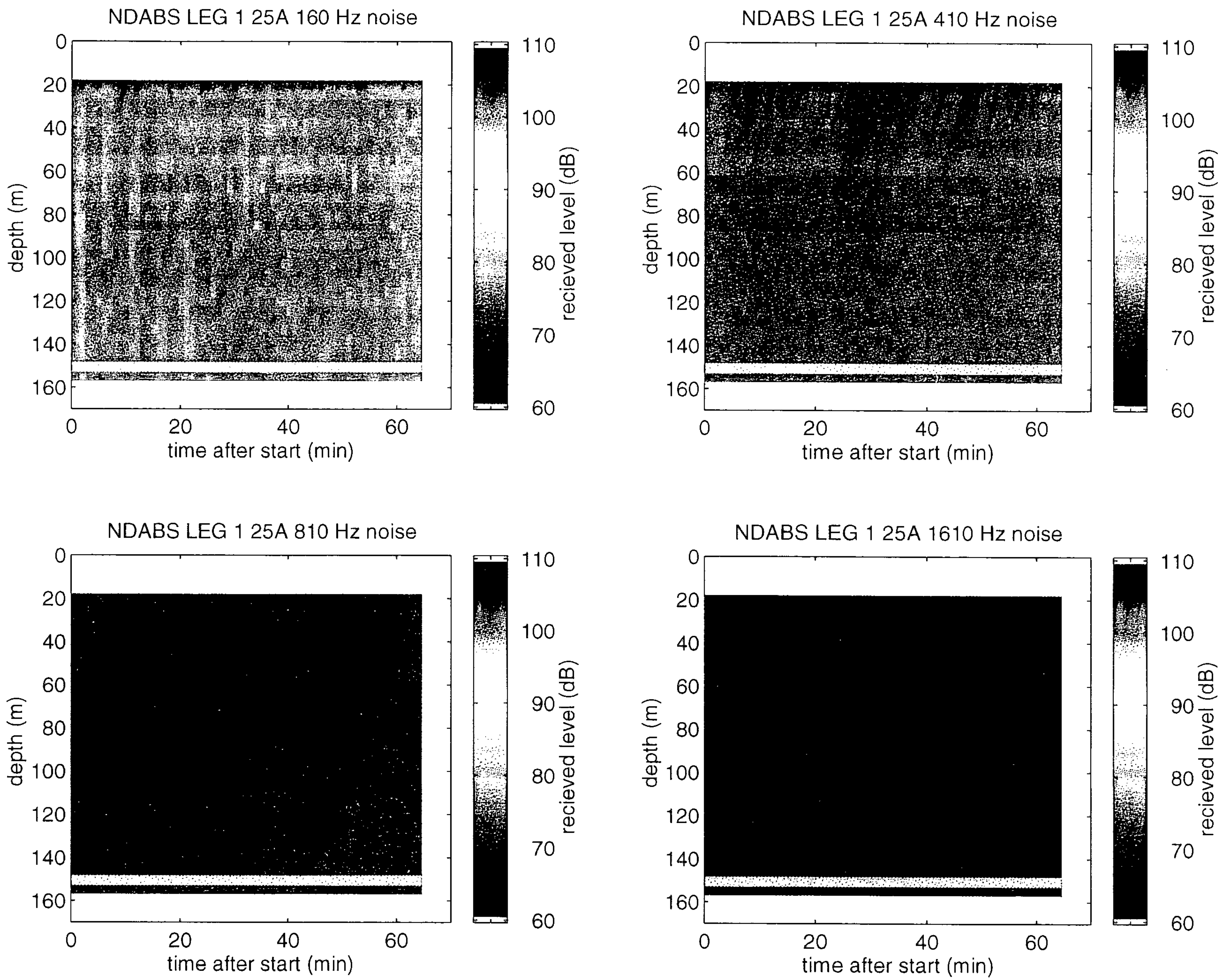

NDABS LEG 1 20A 160 Hz noise
NDABS LEG 1 20A 410 Hz noise
NDABS LEG 1 20A 810 Hz noise
NDABS LEG 1 20A 1610 Hz noise
depth (m)
time after start (min)
recieved level (dB)
0
20
40
60
80
100
120
140
160
200
300
400
500
110
90
70

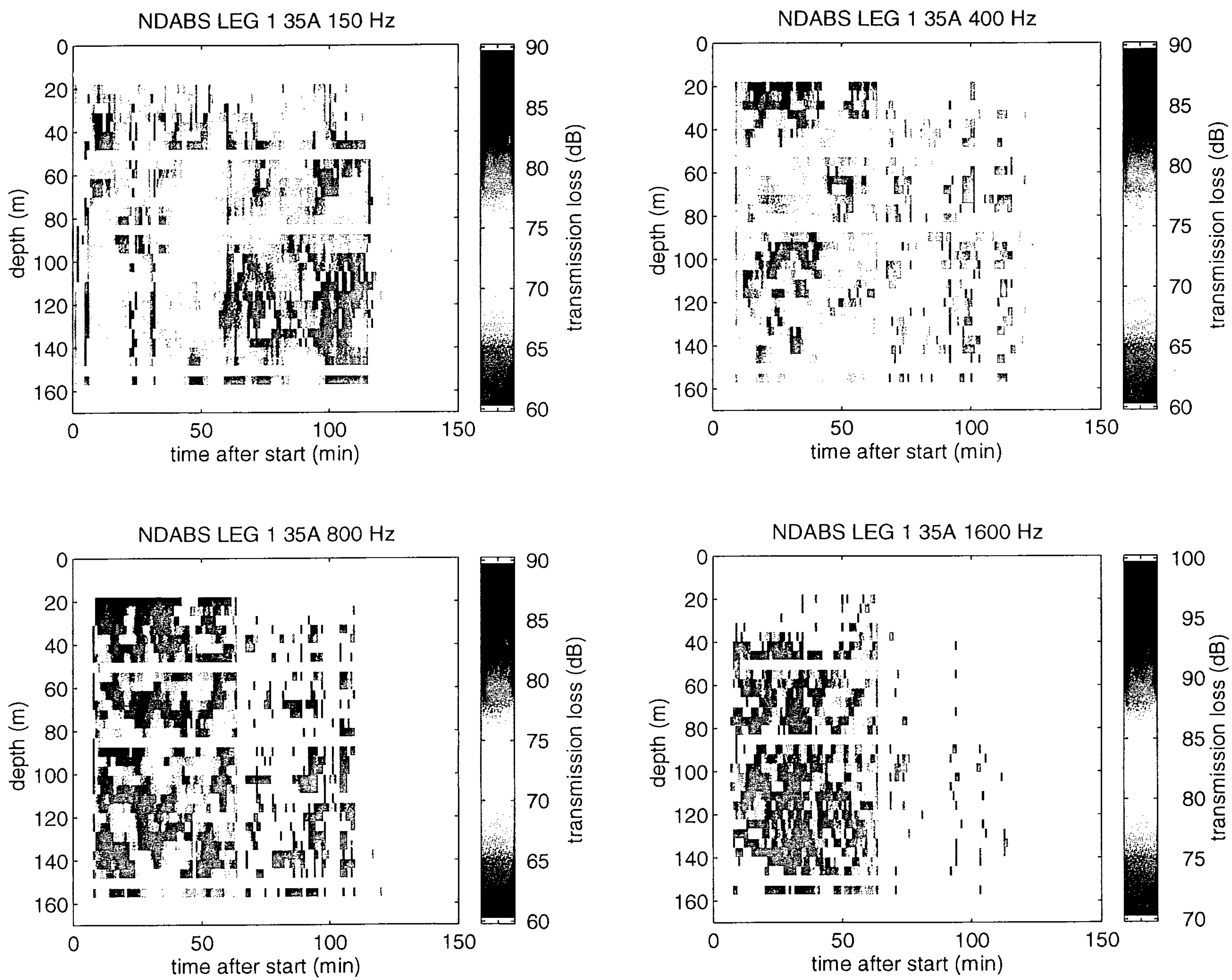

NDABS LEG 1 25A 150 Hz
depth (m)
time after start (min)
transmission loss (dB)

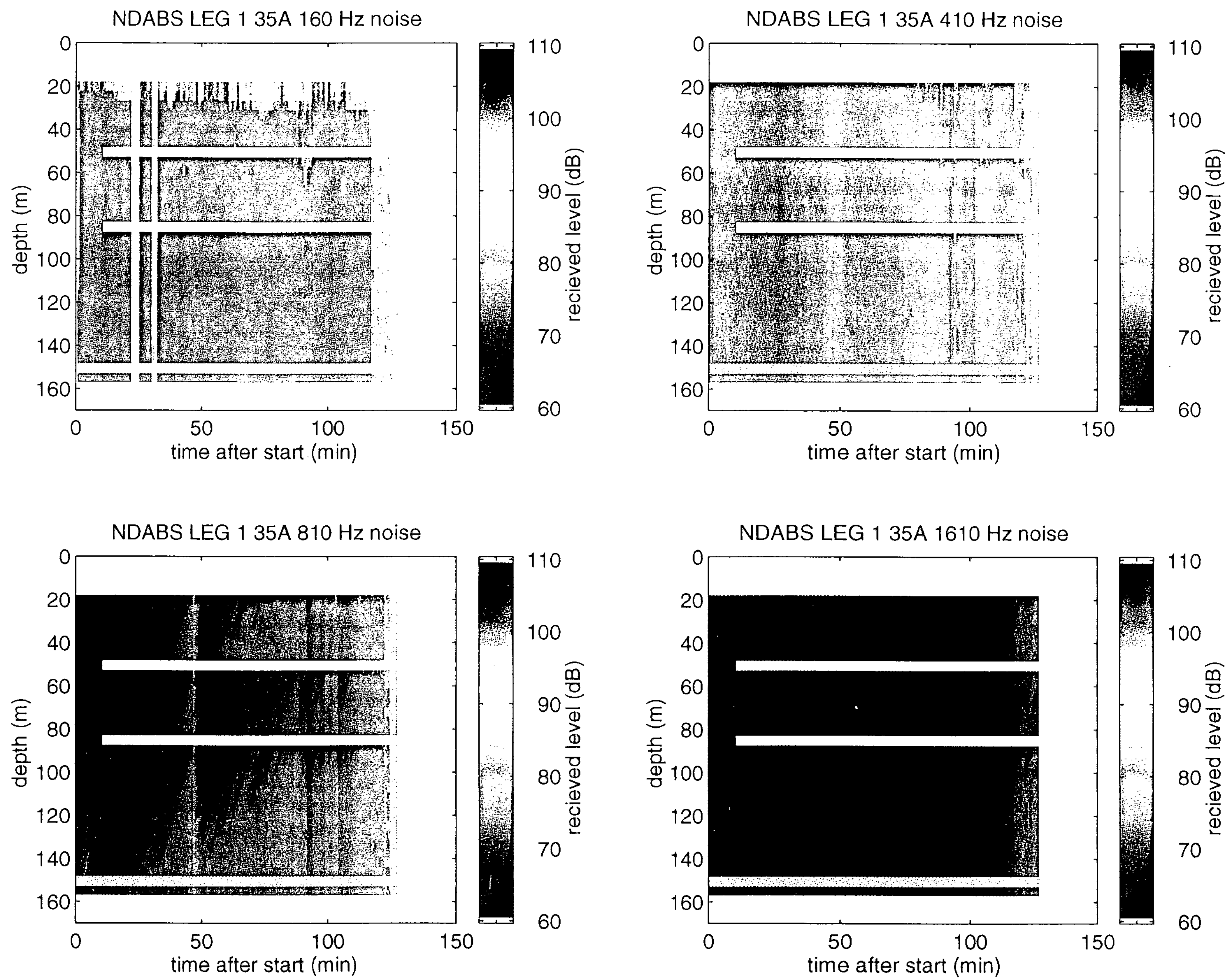

NDABS LEG 1 25A 400 Hz
depth (m)
time after start (min)
transmission loss (dB)


NDABS LEG 1 25A 800 Hz
depth (m)
time after start (min)
transmission loss (dB)

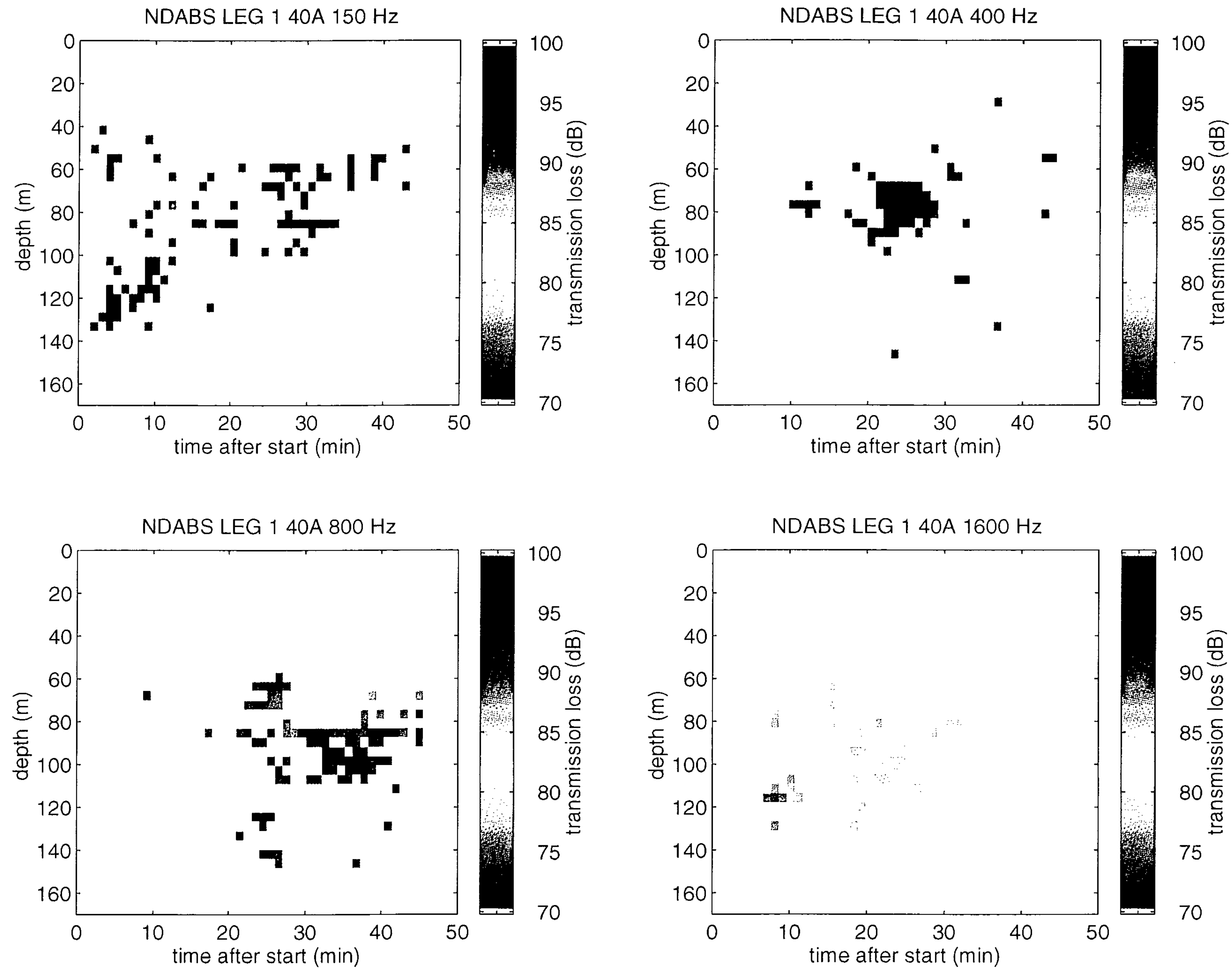

NDABS LEG 1 25A 1600 Hz
depth (m)
time after start (min)
transmission loss (dB)

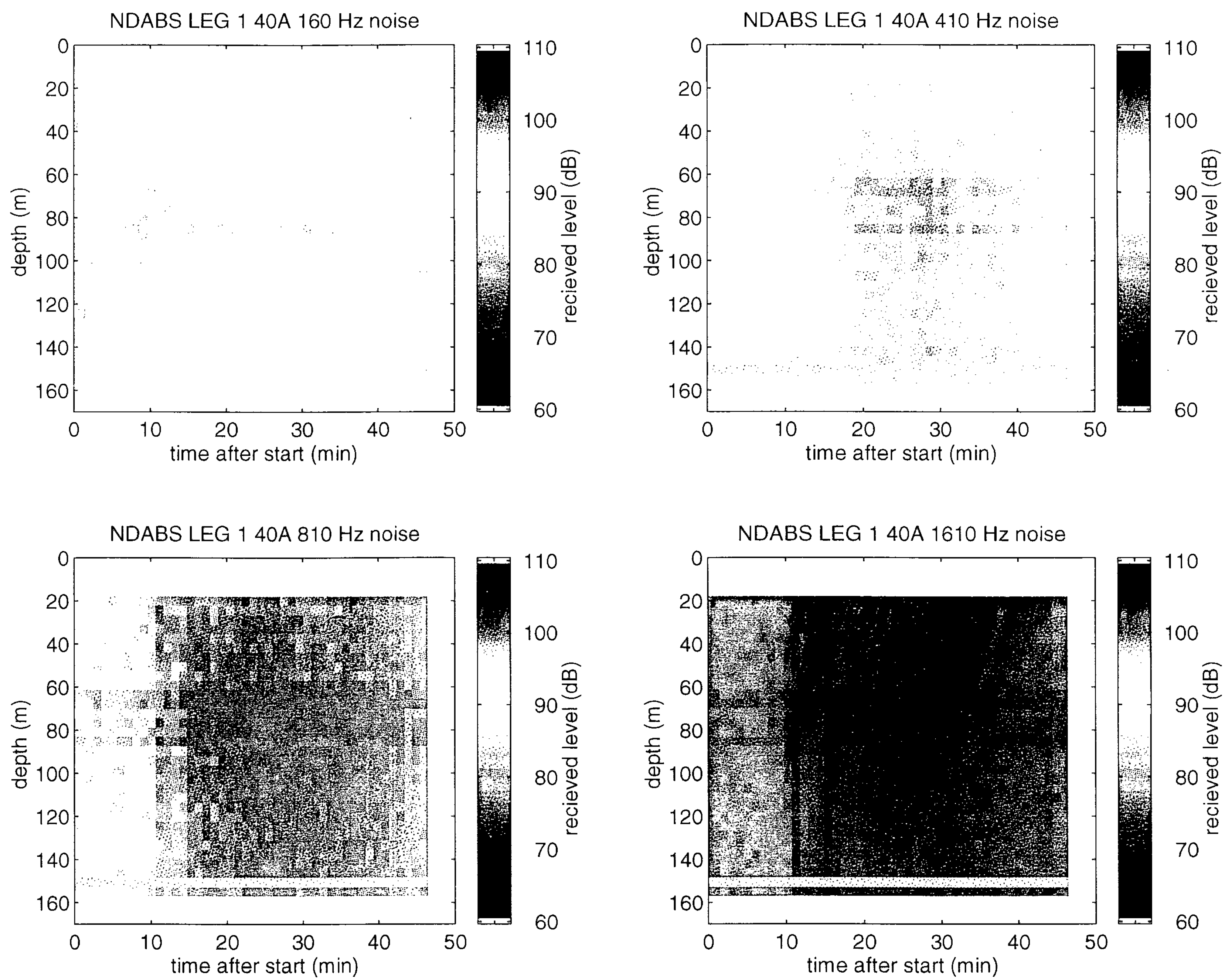

NDABS LEG 1 25A 160 Hz noise
NDABS LEG 1 25A 410 Hz noise
NDABS LEG 1 25A 810 Hz noise
NDABS LEG 1 25A 1610 Hz noise
depth (m)
time after start (min)
recieved level (dB)

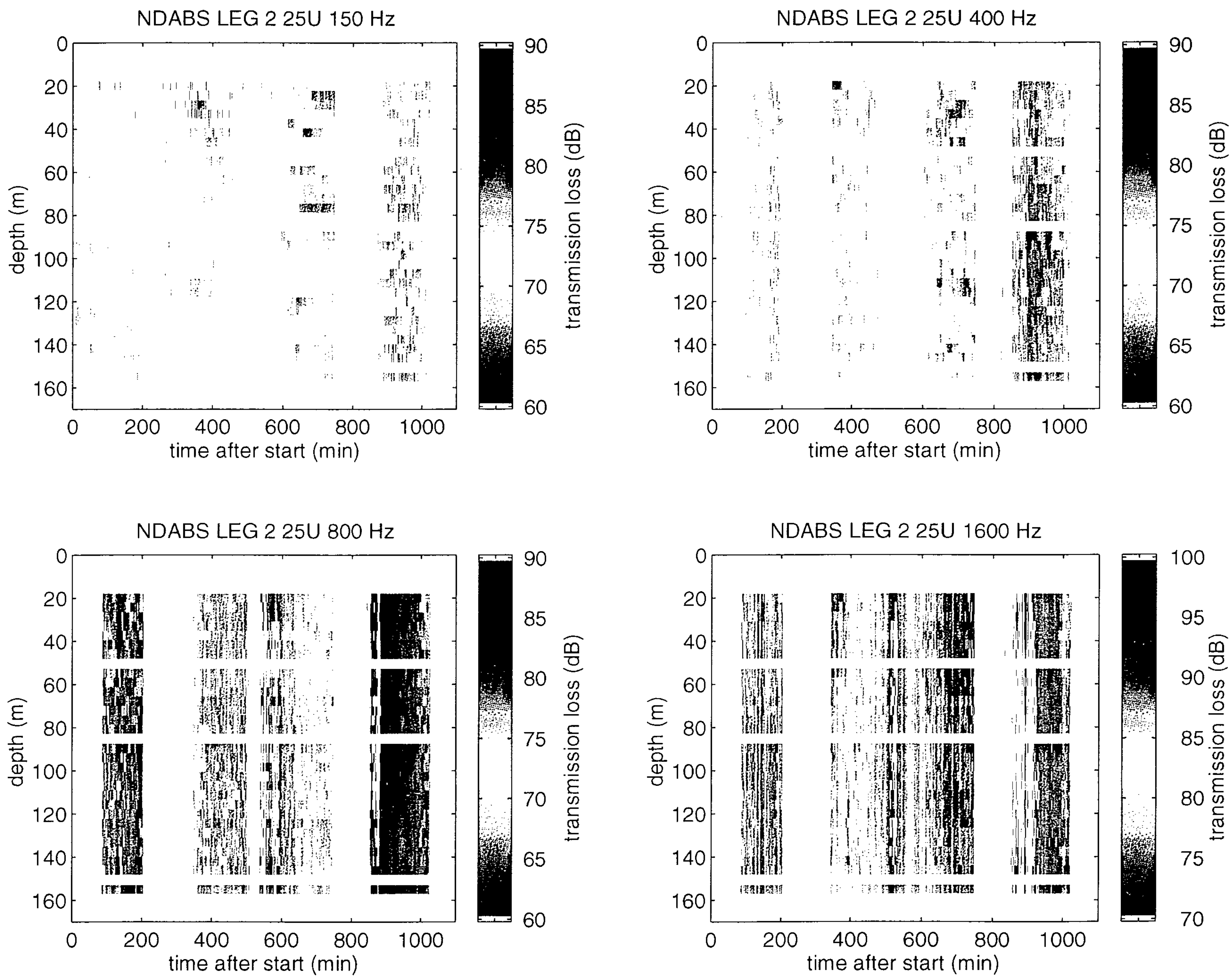

NDABS LEG 1 35A 150 Hz
NDABS LEG 1 35A 400 Hz
NDABS LEG 1 35A 800 Hz
NDABS LEG 1 35A 1600 Hz
depth (m)
time after start (min)
transmission loss (dB)

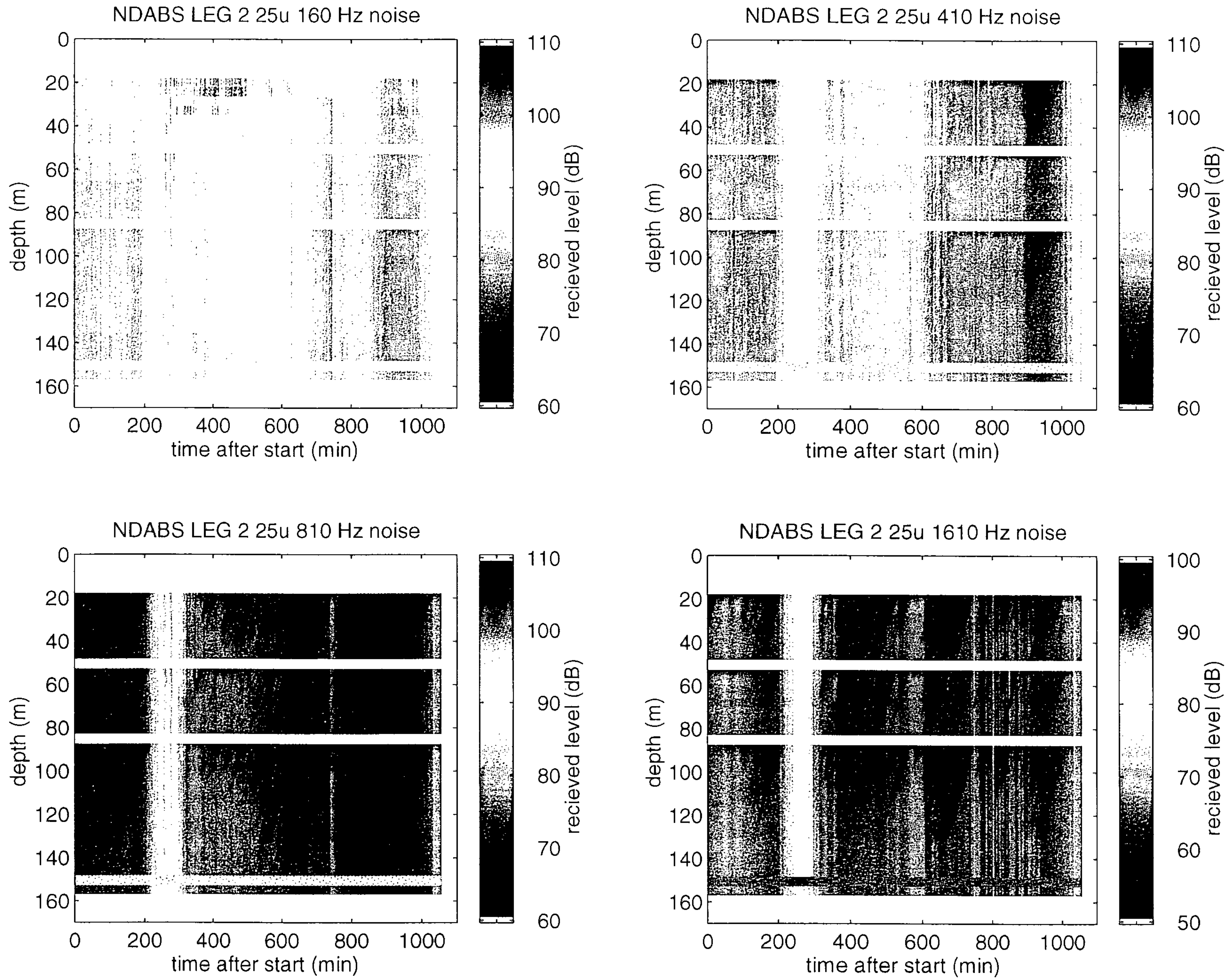


NDABS LEG 1 35A 160 Hz noise
NDABS LEG 1 35A 410 Hz noise
NDABS LEG 1 35A 810 Hz noise
NDABS LEG 1 35A 1610 Hz noise
depth (m)
time after start (min)
recieved level (dB)
0 20 40 60 80 100 120 140 160
0 50 100 150
60 70 80 90 100 110

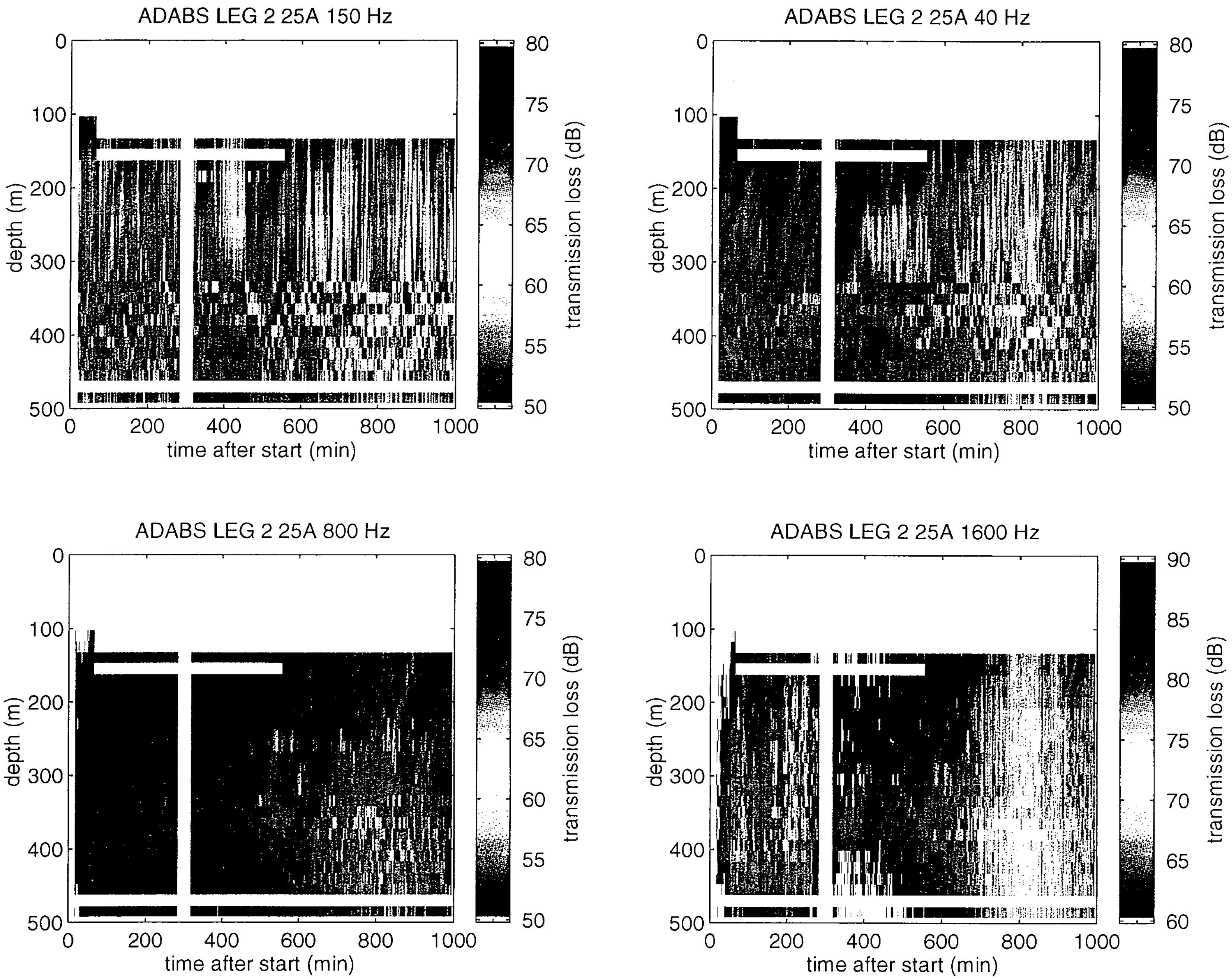

NDABS LEG 1 40A 150 Hz
NDABS LEG 1 40A 400 Hz
NDABS LEG 1 40A 800 Hz
NDABS LEG 1 40A 1600 Hz
depth (m)
time after start (min)
transmission loss (dB)
0
20
40
60
80
100
120
140
160
0
10
20
30
40
50
70
75
80
85
90
95
100

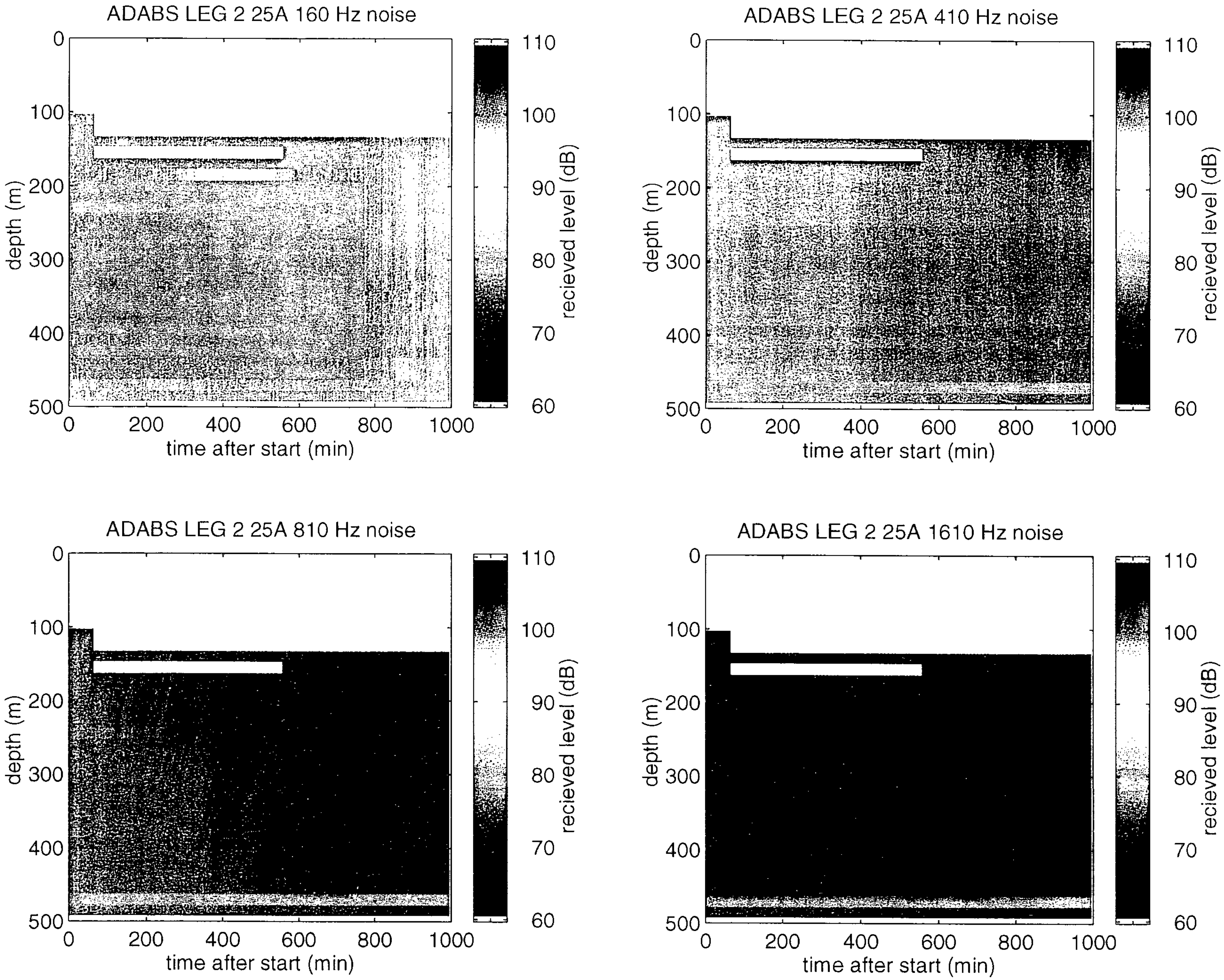

NDABS LEG 1 40A 160 Hz noise
NDABS LEG 1 40A 410 Hz noise
NDABS LEG 1 40A 810 Hz noise
NDABS LEG 1 40A 1610 Hz noise
depth (m)
time after start (min)
recieved level (dB)


NDABS LEG 2 25U 150 Hz
NDABS LEG 2 25U 400 Hz
NDABS LEG 2 25U 800 Hz
NDABS LEG 2 25U 1600 Hz
depth (m)
time after start (min)
transmission loss (dB)

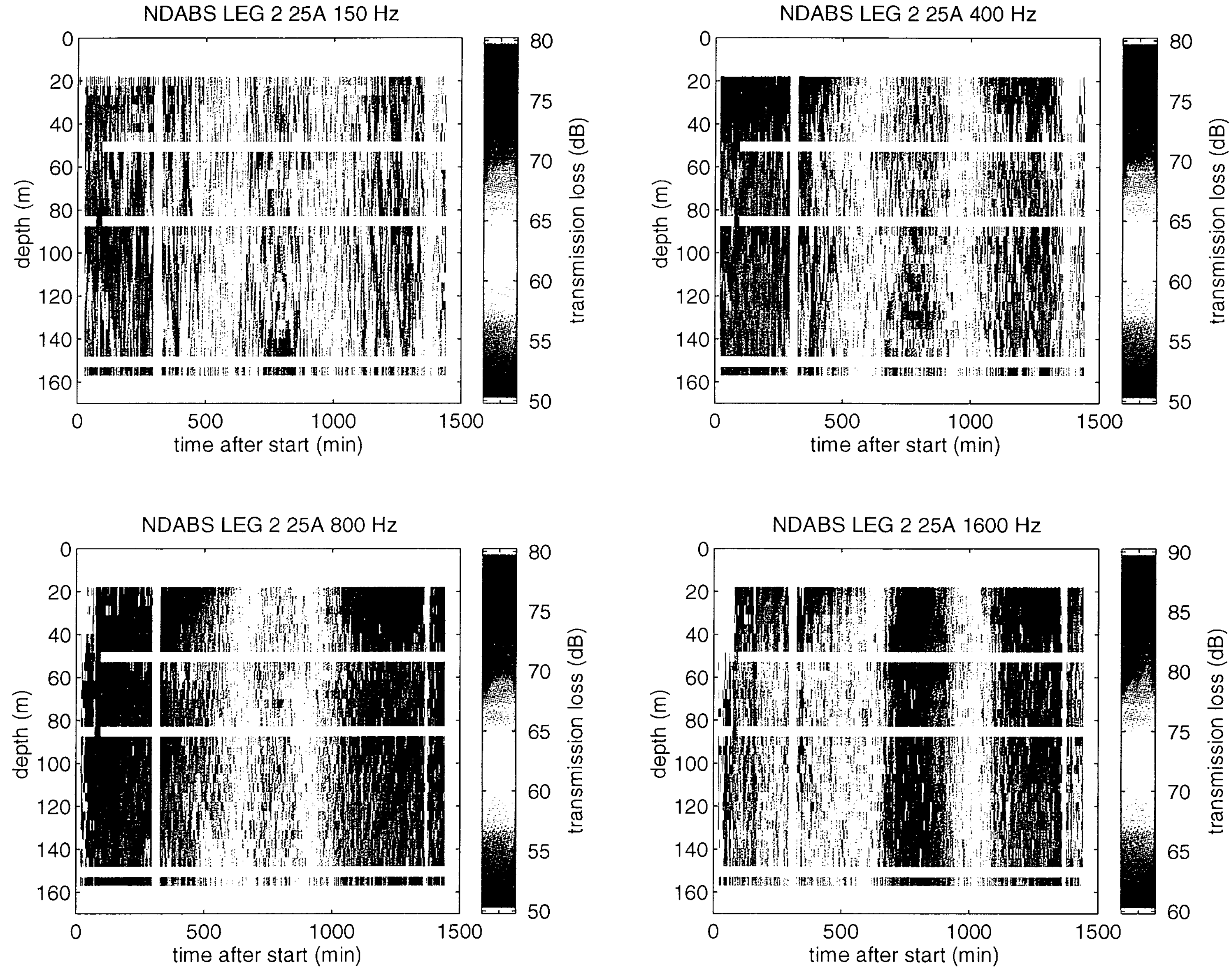


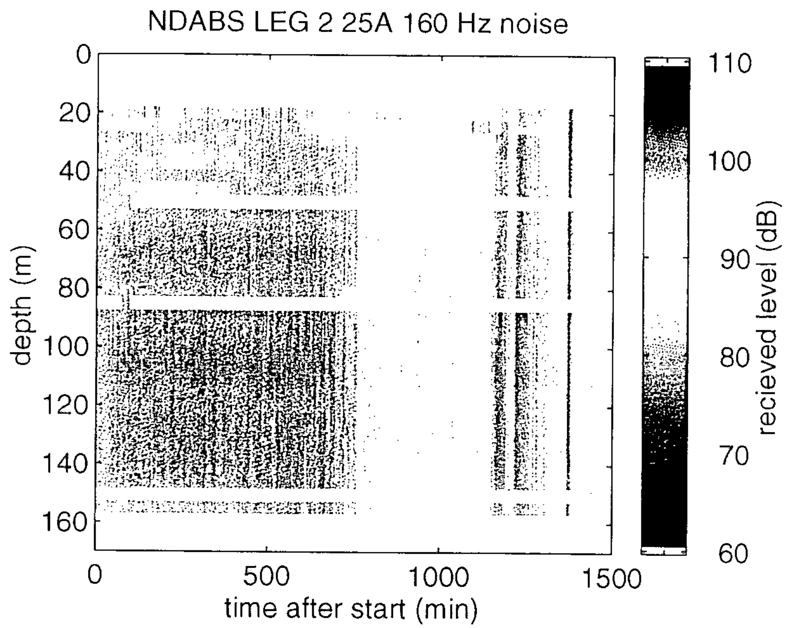
NDABS LEG 2 25u 160 Hz noise
NDABS LEG 2 25u 410 Hz noise
NDABS LEG 2 25u 810 Hz noise
NDABS LEG 2 25u 1610 Hz noise
depth (m)
time after start (min)
recieved level (dB)

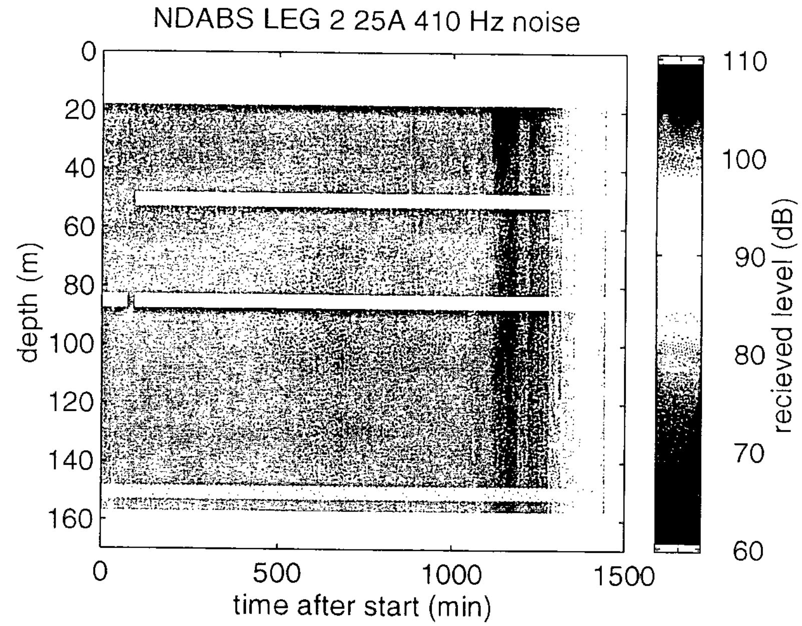

ADABS LEG 2 25A 150 Hz
ADABS LEG 2 25A 40 Hz
ADABS LEG 2 25A 800 Hz
ADABS LEG 2 25A 1600 Hz
depth (m)
time after start (min)
transmission loss (dB)

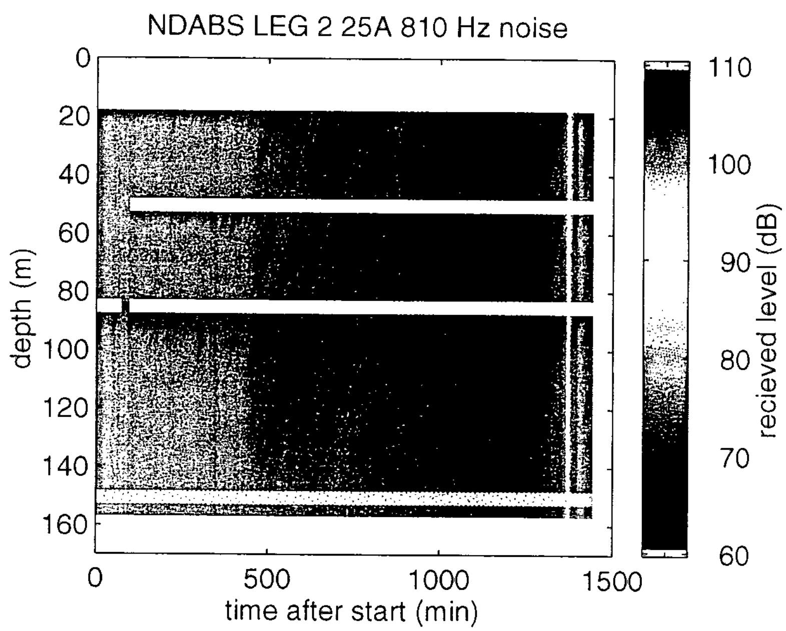


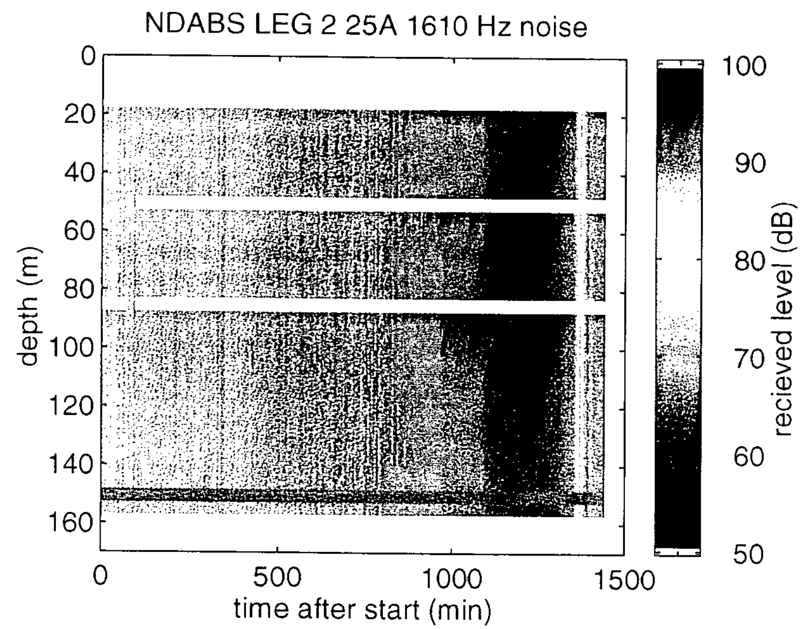
ADABS LEG 2 25A 160 Hz noise
ADABS LEG 2 25A 410 Hz noise
ADABS LEG 2 25A 810 Hz noise
ADABS LEG 2 25A 1610 Hz noise
depth (m)
time after start (min)
recieved level (dB)
0
100
200
300
400
500
600
800
1000
60
70
80
90
110

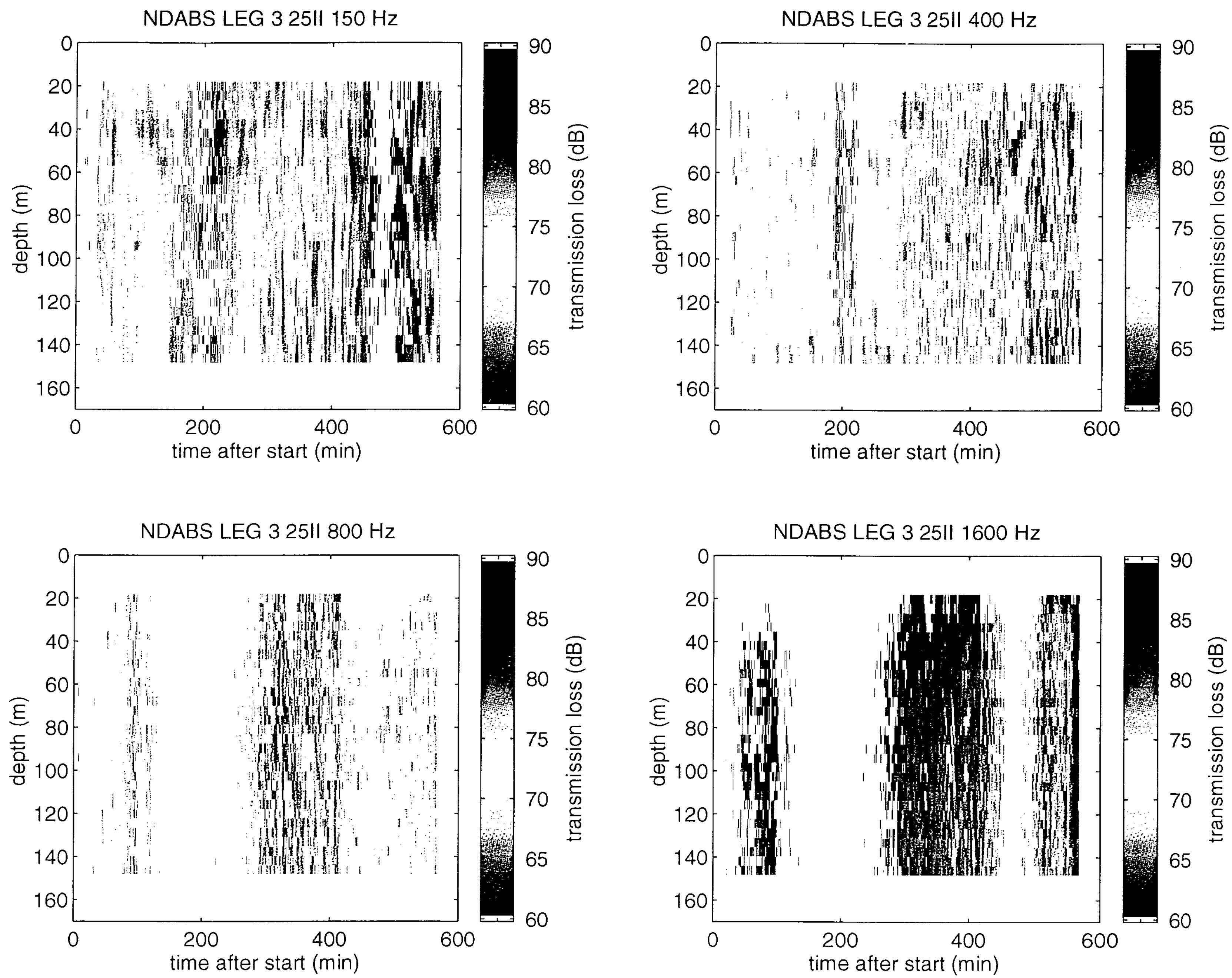

NDABS LEG 2 25A 150 Hz
NDABS LEG 2 25A 400 Hz
NDABS LEG 2 25A 800 Hz
NDABS LEG 2 25A 1600 Hz
depth (m)
time after start (min)
transmission loss (dB)
0
20
40
60
80
100
120
140
160
500
1000
1500
50
55
60
65
70
75
80
85
90

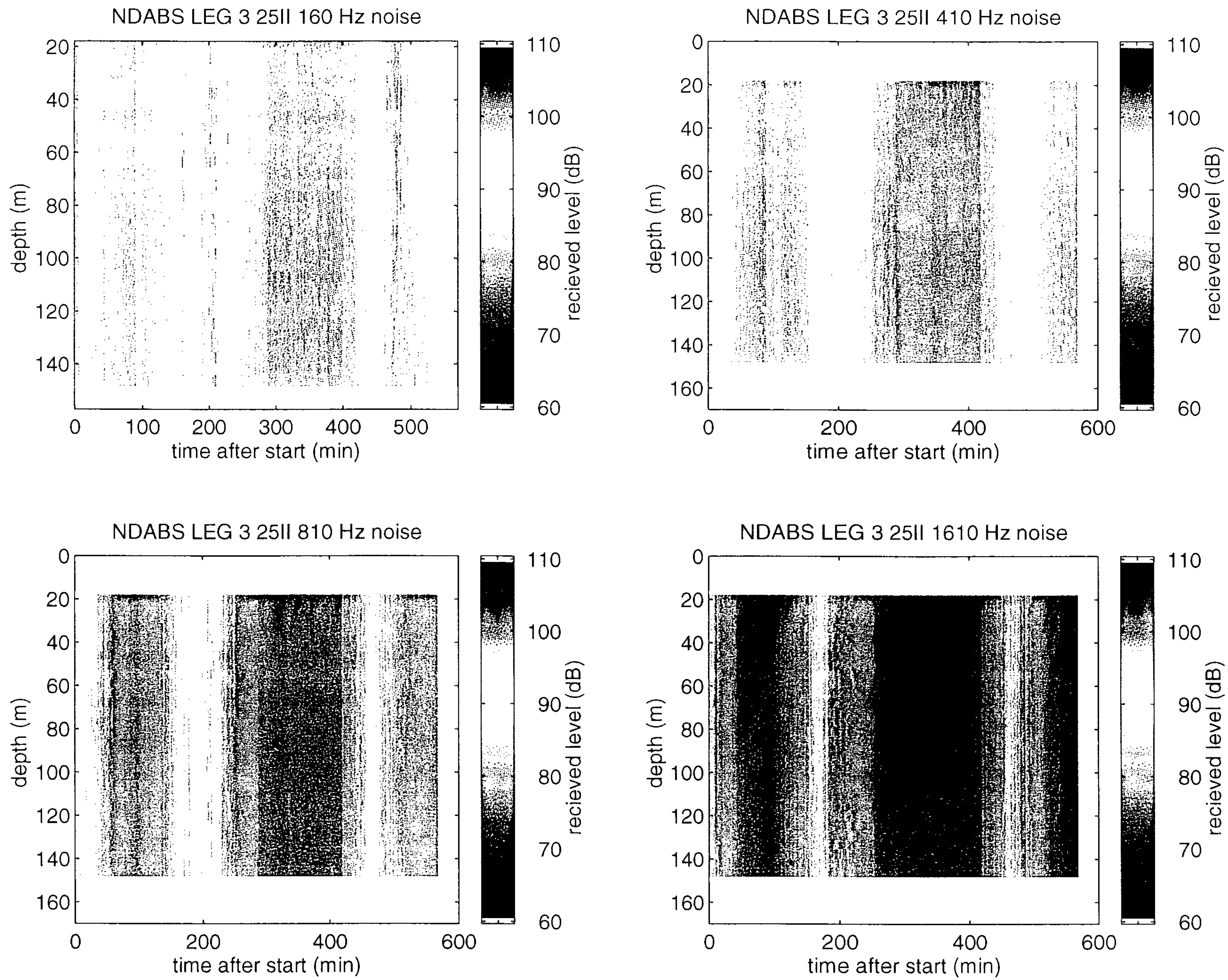

NDABS LEG 2 25A 160 Hz noise
depth (m)
time after start (min)
recieved level (dB)


NDABS LEG 2 25A 410 Hz noise
depth (m)
time after start (min)
recieved level (dB)

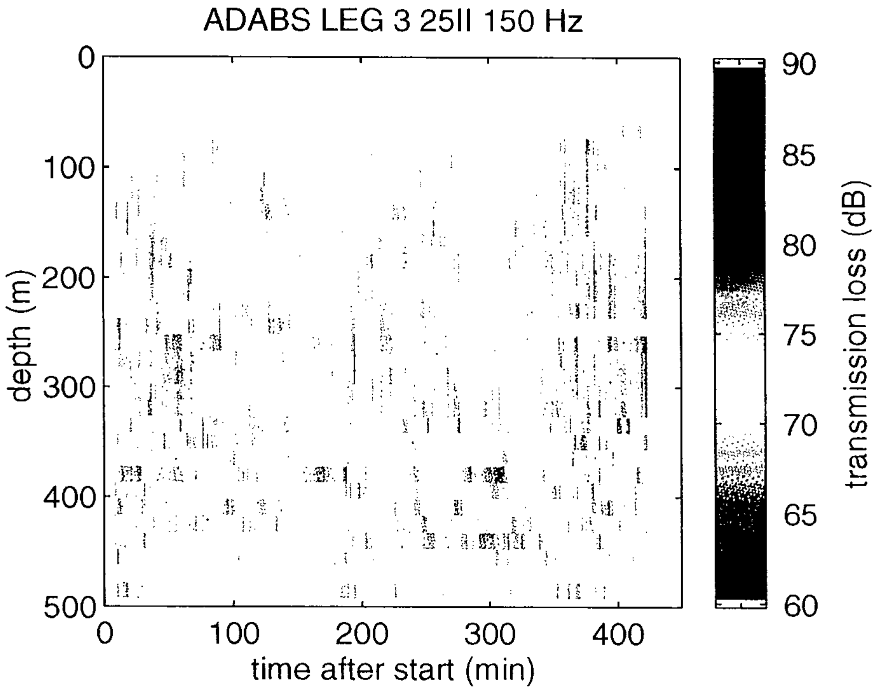

NDABS LEG 2 25A 810 Hz noise
depth (m)
time after start (min)
recieved level (dB)


NDABS LEG 2 25A 1610 Hz noise
depth (m)
time after start (min)
recieved level (dB)

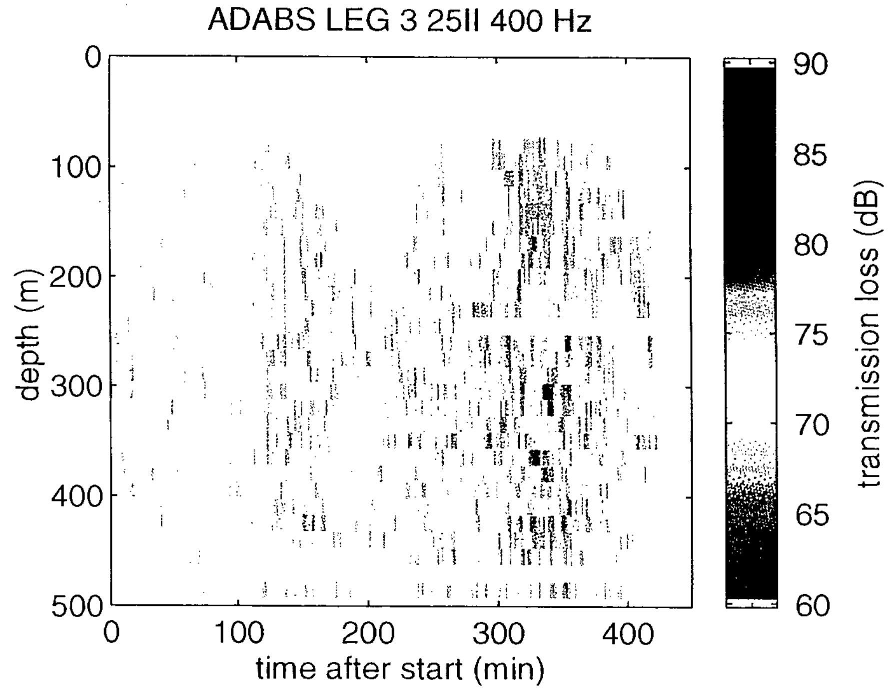

NDABS LEG 3 25II 150 Hz
NDABS LEG 3 25II 400 Hz
NDABS LEG 3 25II 800 Hz
NDABS LEG 3 25II 1600 Hz
depth (m)
time after start (min)
transmission loss (dB)



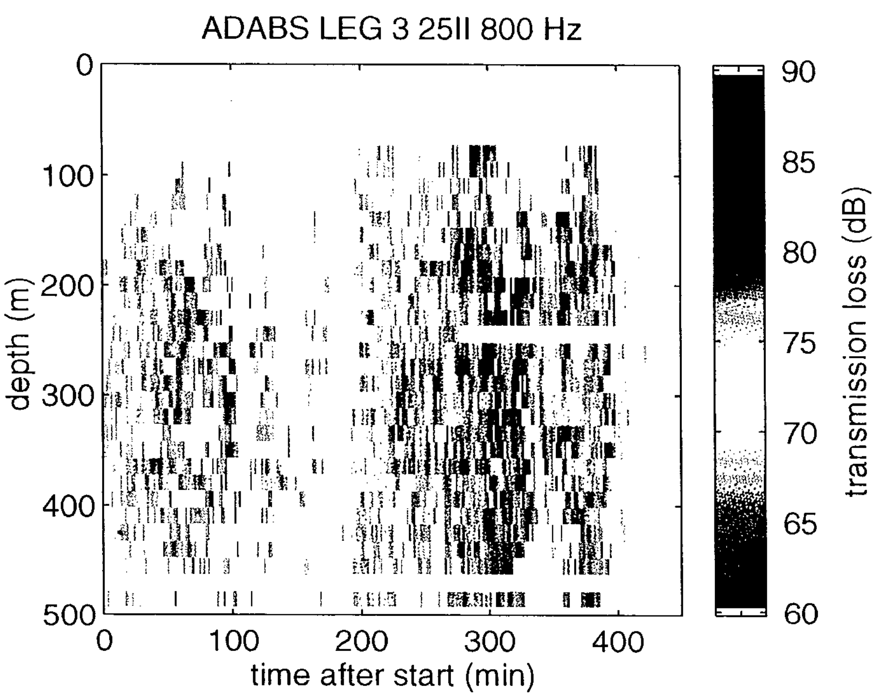
NDABS LEG 3 25II 160 Hz noise
NDABS LEG 3 25II 410 Hz noise
NDABS LEG 3 25II 810 Hz noise
NDABS LEG 3 25II 1610 Hz noise
depth (m)
time after start (min)
recieved level (dB)



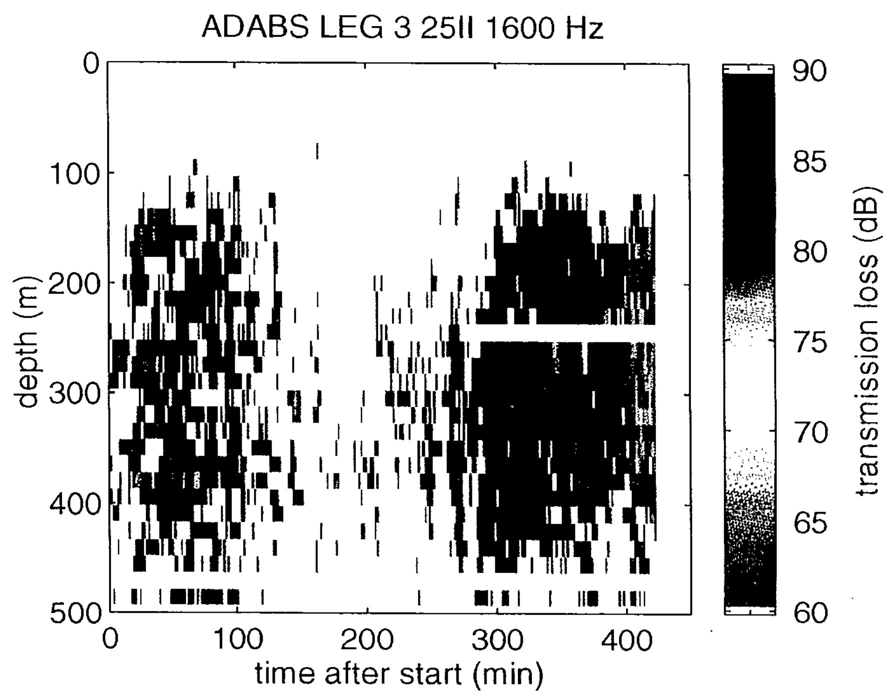
ADABS LEG 3 25II 150 Hz
depth (m)
time after start (min)
transmission loss (dB)



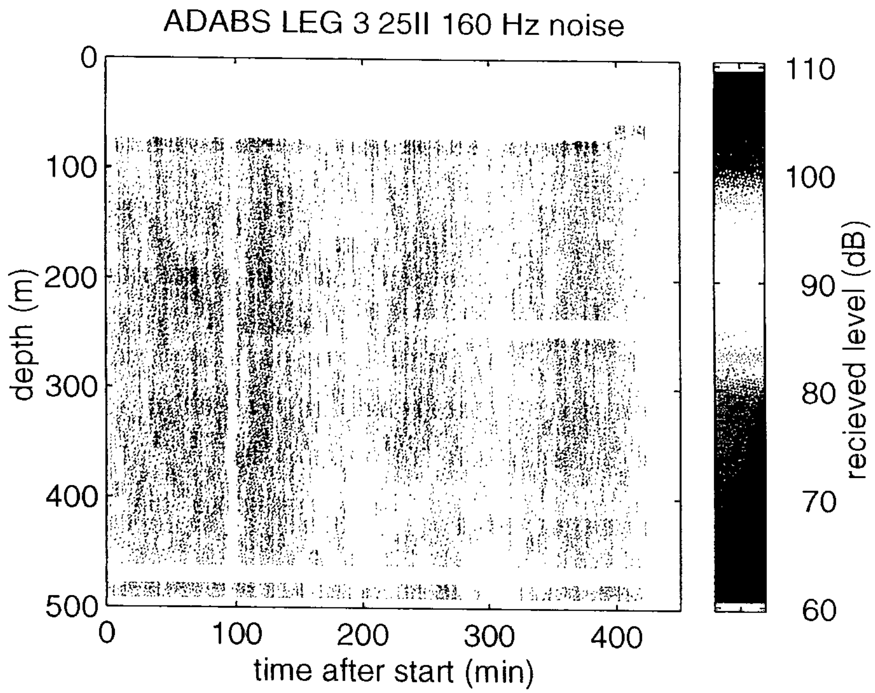
ADABS LEG 3 25II 400 Hz
depth (m)
time after start (min)
transmission loss (dB)

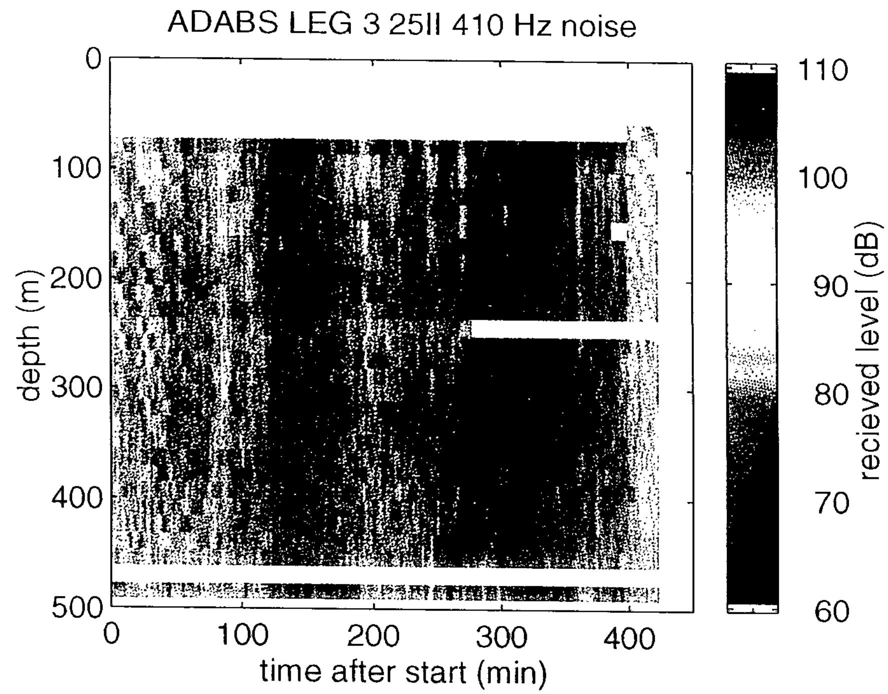


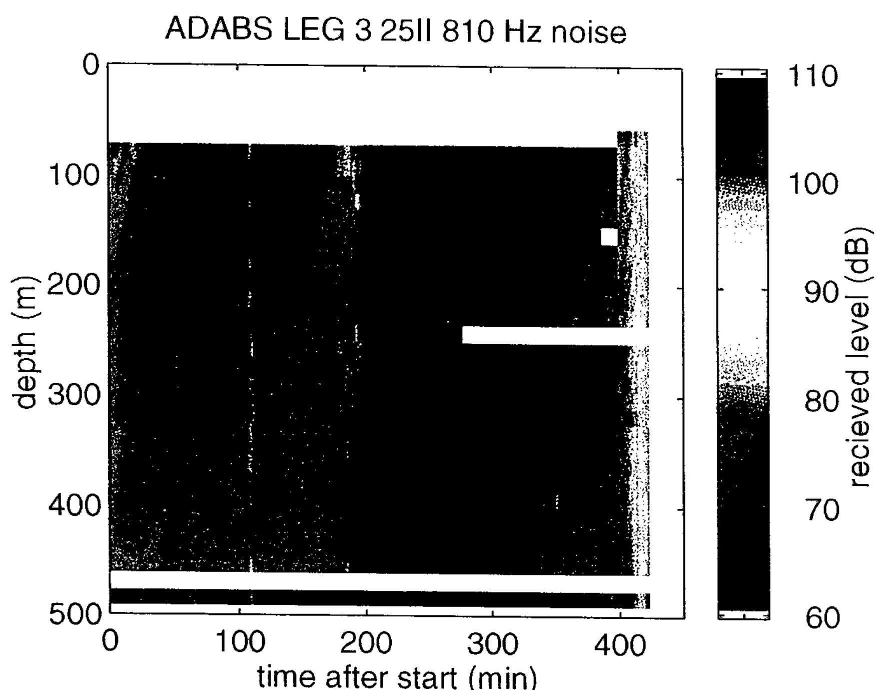
ADABS LEG 3 25II 800 Hz
depth (m)
time after start (min)
transmission loss (dB)

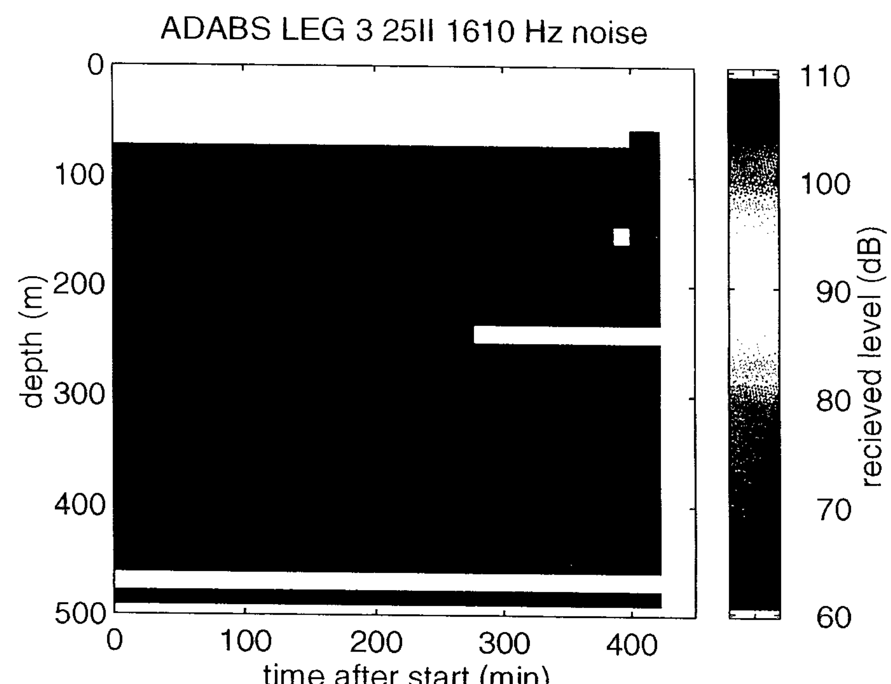


ADABS LEG 3 25II 1600 Hz
depth (m)
time after start (min)
transmission loss (dB)


ADABS LEG 3 25II 160 Hz noise
depth (m)
time after start (min)
recieved level (dB)


ADABS LEG 3 25II 410 Hz noise
depth (m)
time after start (min)
recieved level (dB)


ADABS LEG 3 25II 810 Hz noise
depth (m)
time after start (min)
recieved level (dB)


ADABS LEG 3 25II 1610 Hz noise
depth (m)
time after start (min)
recieved level (dB)